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Forecasting Research Division
Technical Report No. 87

Operational changes affecting the quality control of atmospheric data used by the Unified Model during 1993

by

Colin Parrett
March 1994

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1. Introduction

This report documents operational changes through 1993 that affected the flagging of atmospheric data by the Unified Model (UM) quality control (QC) scheme - the QC scheme is described in Ingleby and Parrett (1994). It follows on from the report by Parrett (1993a), subsequently referred to as P93, which discussed the changes from November 1991 to the end of December 1992. To aid comparison, the format here is similar to that in P93, with the same sequence of data types, etc.. Time-series are presented first, in section 2, showing the percentages of rejections for most observation types; these help illustrate the effects of the changes. In section 3, more detailed statistics are presented for October 1993; these are compared with similar statistics for October 1992 presented in P93.

2. Changes related to the time-series of rejections

The time-series presented here cover the whole of 1993. They have been produced from data stored in the global model observation processing database (OPD), using the Statistical Analysis Software (SAS) and SAS/GRAPH packages. As in P93, the statistics are calculated for each week beginning on a Tuesday, because the operational changes are normally made on Tuesdays - a list of the changes (and other incidents) that may have affected the statistics is given in Appendix A.

Although not strictly within the remit of this report, the effect of the quality control change on 8th February 1994, to include a sonde-aircraft buddy check, is included as Appendix B.

The number of observations of each data type in the OPD are displayed in Figure 1 (N.B. 120km Satems and ERS1 scatterometer winds are not stored in the OPD). There are few substantial changes for most data types. Many of the dips in numbers were either due to temporary problems with transmission/receipt of data (e.g. most of the many dips in numbers of drifters and satobs), or due to problems with archiving the OPD (e.g. all February Satem data lost), sometimes caused by other operational problems (e.g. during the first week in August). Other points to note are:

(i) the large increase in Aireps on 9th March, when Aireps bound for ECMWF were also sent to the SDB/OPD - these included many duplicates;
(ii) the large drop in Airep numbers on 13th September when Aireps received from Carswell were no longer used (removing most of the duplicates);
(iii) Asdars were not stored in the OPD after 9th November;
(iv) reports from moored buoys and platforms/riggs were assigned separate model observation types to ship reports on 2nd November, resulting in the drop seen in the number of ship reports.

2.1 Surface observations

(a) Pressure

Figures 2(a)-(c) show the percentages of pressure rejects for synops, ships and drifting buoys, respectively. Figure 2(a) shows the usual seasonal trend in the percentage of synop pressures flagged, with an increase in flagging in the northern hemisphere winter (not evident for ship pressures - Figure 2(b)). This may be due to model boundary layer problems or local effects over land causing large differences from background. There was a temporary increase in the percentage of synop and ship pressure flags for the week beginning 2nd February, which may have been associated with instabilities near the top of the model producing rough background pressure fields; bullseyes were seen in the P_{msl} forecasts by T+48, resulting in the change made on 5th February to increase diffusion at levels 18 and 19. There was a permanent increase of ~0.7% in final flags of synop pressures on 7th September, due to the change to flag those stations not reporting a station height (this change has since been reversed, on 4/1/94).

Figures 2(b) and 2(c) show a larger weekly variation in percentage of ship and drifting buoy pressures flagged than is seen in the synop time-series. This is partly due to the greater variability in the numbers of reports, the smaller numbers involved and different ships reporting each week. The monthly updates to the ship and drifter permanent rejection and correction lists impact on the percentage with a final flag directly and may have a small effect on the percentage with buddy check flags if

more or less bad reports get through to the buddy check (permanent rejects are not buddy checked).

The percentage of drifting buoy pressures flagged by the background check shows a similar annual cycle to that exhibited by the synop pressures; although the percentage flagged after the buddy check shows much less variation, i.e. the buddy check reinstated more observations in the northern hemisphere winter. Figure 2(c) also shows a steady increase through 1993 in the percentage of drifting buoy pressures given a final flag - either permanent rejects or 'thinned' within the quality control (Ingleby and Parrett, 1994).

(b) Wind

The time-series of ship wind reports, Figure 2(d), shows an annual cycle in the percentages rejected, more noticeable in the background flags than in the flags after the buddy check (as for drifter pressures). The largest change to the background/buddy check flags was on 2nd November, when winds from moored buoys and platforms were given a different model observation type to those from ships and were excluded from the plot. The rise of nearly 1% implies that the winds from moored buoys and platforms were generally better than those from ships, and this was seen in a study by Leighton (1993a) from 1992. The rise in percentage of flags was followed by a smaller drop the following week, when the moored buoy and platform winds were removed from the assimilation for a week; this was to facilitate a change to the height at which they were assimilated, from model level 1 (~25m) to 10m, their nominal height. Many of the updates to the permanent rejection list resulted in changes in the percentage of ship winds with a final flag.

2.2 Aircraft observations

The time-series of Aireps above 400hPa are shown in Figures 3(a) and 3(b). There was a large decrease in final flags of both wind and temperature on 2nd February, due to the removal of all but one airline's aircraft from the permanent rejection list. Also on 2nd February, improvements were made to the duplicate check and

a track check was introduced; these changes resulted in a rise in background and buddy check flags of ~0.5% (unless the UM change to include ∇^4 diffusion at levels 18 and 19 also contributed?).

There was a sudden rise in final flags of both Aireps and Asdars (Figures 3(c) and 3(d)) on 4th May, which was due to the correction to the setting of flags for each element [prior to the correction, the whole reports were flagged and not used in the assimilation - the correction only affected the OPD results]. The large spike in final flags for the week beginning 7th September was due to the automatic aircraft data being extracted from the MDB and consequent flagging of duplicate data from the SDB. This only lasted one week, because on 13th September all data received from Carswell (~95% of which were either duplicates or had wrong positions, R.S.Waters, pers.comm.) were no longer extracted - this accounts for the dramatic drop in the number of Aireps seen in Figure 1. The drop in the percentage of final flags on 9th November was due to the permanent rejection list being updated.

As in 1992 (P93), the percentages of Airep background flags show something of an annual cycle, peaking at 3.0% in February and troughing at < 0.5% in September. After March 1993 there were fewer background flags than in 1992, although the percentage of buddy check flags was similar to that in 1992. The reduction in the observation errors on 3rd August had little impact on flagging rates of either Aireps or Asdars. The introduction of synoptic-dependent background errors (BGEs) on 16th November, and associated changes to the observation errors and initial PGEs for aircraft winds (see Parrett, 1993b, for details), also had little impact on the percentages of Aireps and Asdars flagged; the only noticeable change was a slight reduction in the percentage of Airep winds failing the background check.

The percentage of Asdars with background/buddy check flags (Figures 3(c) and 3(d)) remained much lower than for Aireps, being generally < 0.2%, reflecting the higher quality of the automated data. The peak in the percentage of background flags in March was partly due to the faulty Asdar, CO00624Z, which got gradually worse (Smith, 1993a) before being permanently rejected on 23rd March. Cruise level temperature reports from Asdar PH012UMZ/

KL012UMZ were found to have an observation-background (o-b) bias of 1.7°C (Smith, 1993b) and were blacklisted from 8th June; this caused an increase of ~5% in final flags, seen in Figure 3(d). Asdar data ceased to be stored in the OPD on 9th November; from this date all automatic aircraft data have been stored in the Meteorological Data Base (MDB).

2.3 Satellite cloud track-winds (Satobs)

Figures 4(a)-4(c) show time-series of background flags for the high, medium and low level satellite cloud-track winds that are used operationally. [Data from the Indian satellite INSAT are deemed to be of poor quality (e.g. Leighton, 1993b) and are not used operationally.] The low level winds have much lower rejection rates than medium and high level winds, probably because of the better resolution and persistance of the low level clouds (e.g. trade wind cumulus clouds).

As in 1992, the winds from Meteosat seem to be the best quality, with the lowest rejection rates: generally less than 3% at high and medium levels, and ~0.1% at low levels during the first half of 1993, then increasing somewhat (to be similar to GOES and GMS rejection rates for the last half of 1993). There was little change in the flagging rates when the rejection list was updated on 2nd February, although there was a general trend for the percentage of flagged high level winds from both Meteosat and GMS to decrease through the year. There seems to have been no impact on flagging rates with the inclusion of infra-red Satobs from Meteosat in November.

Winds from the Japanese satellite (GMS) have the second lowest rejection rates: at high levels, falling from ~5% prior to mid-April down to less than 1% in November and December (comparable to Meteosat rejection rates); and averaging ~0.35% at low levels.

GOES winds have the highest rejection rates, little changed from 1992: approximately 17-30% at high levels, 10-22% at medium levels and 0.3-1.2% at low levels. Many of the rejections were caused by large o-b temperature differences, which were due to

problems with the height assignment of Satobs at NESDIS (e.g. assigning Satobs to levels in the stratosphere!); the large values of o-b temperature produced high values of probability of gross error (PGE) in location (see Ingleby and Parrett, 1994), which led to the flagging of the GOES winds, even if they were close to the background wind. The weight given to the o-b temperature values within the QC will be reassessed after NESDIS have improved their height assignment (possibly Spring 1994).

2.4 Bogus observations

The percentages of bogus pressures (Figure 5(a)) and upper winds (Figure 5(b)) flagged by the background check were generally less than 1% and 2%, respectively; but the percentages varied greatly from week to week, reflecting the variability in quantity and location of bogus observations. The buddy checking of bogus pressures against other surface pressure observations (bogus observations do not buddy check each other) usually flagged more bogus pressures than it reinstated. There is no buddy checking of bogus upper winds. The differences between the percentages of buddy check and final flags in Figures 5(a) and 5(b) were caused by bogus observations that were very far from the background values (flagged by the background check) and not used in the buddy check; although some of the differences in Figure 5(a) may have been due to some bogus observations being over model land points with an elevation in excess of 1000m - these are given prior reject flags.

Figure 5(b) shows a general trend for the percentage of flagged bogus winds to have decreased during 1993, continuing the trend seen in 1992 (P93). This trend may be attributed to increasing experience of the intervention forecasters in CFO - not trying to insert winds with values very far from the background.

On average, there were approximately 120 bogus thickness observations produced each week, very few of which were flagged - most weeks none. For most of the weekly periods no bogus upper level temperatures or relative humidities were flagged either, although for just 2 and 3 weeks, respectively, more than 5% were flagged.

2.5 NESDIS 500km satellite soundings (Satems)

Figure 6 shows that the percentage of Satems flagged in the troposphere by the stability check (Ingleby and Parrett, 1994) remained relatively constant at about 20%, similar to the percentage flagged during 1992 (P93). The percentage of soundings with a background flag at any level was about 40% until the end of March, then decreased slowly to ~35% by 4th May, when it apparently dropped to around 15%. This sudden drop was caused by the QC change to set final flags on all elements when a whole report is flagged - no other flags are set in this case; i.e. from 4th May, none of those Satems co-located with 120km Satems Sat120s) have had any background flags set. Excluding these prior rejects, the percentage of background flags only fell slightly from 34% in April to 30% in May.

The soundings with a tropospheric or stratospheric flag are those failing a multi-layer check on all layers below or above 100mb - at least 2 suspect layers or 1 flagged layer, away from the bottom or top layer, respectively. The percentage of these flags was generally < 1%, although the percentage of stratospheric flags was slightly higher (1-2%) up to the end of March and again after mid-October; for this latter period there were known problems with temperature biasses near the top of the model. These biasses were caused by inaccurate one-sided differencing in the vertical analysis of satellite soundings, particularly the top layer of Sat120s (10-5hPa). The problem has since been rectified (on 25th January 1994), by a change to not increment model levels where the model layer is not completely covered by the observation layer.

The low percentages of prior and final flags of Satems for the week beginning 2nd March, was due to there being no Sat120 data for the period 1st-9th March; most of the prior rejects are where Satems are co-located with Sat120 soundings. Other dips in the percentage of final flags are mostly due to temporary problems with receipt of Sat120 data, e.g. the week beginning 12th October.

2.6 Radiosonde observations

The time-series of percentage of radiosonde flags, split into three pressure bands, are given in Figures 7(a)-7(i). Generally, the percentages of background flags during 1993 are similar to the percentages flagged during the 2nd half of 1992 (cf Figures 8(a)-8(i) in P93). There seems to be a small seasonal trend in the percentages of background flags, with higher values in the northern hemisphere winter. This is most noticeable in the winds, particularly at higher levels (Figure 7(a)), where the increased jet strengths leads to higher o-b values and higher flagging rates. The introduction of synoptic-dependent BGEs on 16th November should have reduced the extra flagging in strong wind situations, by increasing the BGE; and indeed the flagging did decrease at higher levels, whereas it remained approximately constant at lower levels where the winds would have been lighter (Figure 7(g)).

For the week beginning 9th February, there was a drop in the percentage of upper and medium level winds flagged (and low level temperatures), which may have been due to the UM change on 5th February to use ∇^4 diffusion at model levels 18 and 19, in the absence of any other changes. The introduction of UM version 3.0 on 23rd February, with its new orography and land/sea mask, seems to have led to a general reduction in flags of wind and temperature, except at mid-levels where there was a small increase.

The drop in the percentage of background and final flags of both wind and temperature above 400hPa on 23rd March, may (like some of the other changes) have been due to a change in the weather regime over one or more of the data dense areas in the northern hemisphere; possibly helped by the permanent rejection of Asdar CO00624Z - removing an erroneous source of data and allowing the background fields to improve somewhat.

The introduction of UM version 3.1 on 25th May was accompanied by a drop in the percentage of temperatures above 400hPa flagged by the background check. This was associated with the previous warm bias in the model compared to sonde temperatures (Leighton,

1993b) becoming a much smaller (cold) bias with the change to the vertical interpolation.

The change to use model level background data, instead of pressure level fields, on 6th July, was associated with an increase in flagging of low level temperatures, seen in Figure 7(h). This was due to inconsistencies in the interpolation to and from model levels and to the use of sonde data below the model surface. The flagged percentage fell again on 9th November, when reported levels below the model surface were given permanent reject flags and excluded from the vertical averaging.

The minor change to the vertical averaging on 3rd August seems to have had little impact on the flagging rates; and the correction to the vertical averaging on 5th October was effectively a 'null' change. There was a temporary increase in the flagging of sonde winds for the week beginning 9th November, possibly associated with the change to use model background data to convert Pilot heights to pressures (or it could just be 'noise' in the time-series).

Figure 7(c) shows that the largest change to the percentage of humidity flags was on 2nd March, when the -40°C cutoff was reintroduced, resulting in more than 70% of humidities above 400hPa being flagged. The lower percentage of final flags in the northern hemisphere summer is due to the -40°C isotherm being higher then. The drop in low level humidity flags on 4th May (Figure 7(i)), may have been associated with the change to the extraction of sondes, in the absence of any other changes. The much higher percentage of background flags for humidity at high levels, is associated with the large variation in humidity across the tropopause and problems in modelling and observing this.

3. Statistics for October 1993

This section contains a summary of the quality control decisions in October 1993. October was chosen so that comparisons can be made with the results for October 1992, presented in P93 (October 1992 results are given in brackets and italics in the text below). As in P93, contingency tables are used to compare the background and buddy check flags, etc., and horizontal bar charts are used for multi-level data.

3.1 Surface

Table 1(a) shows that 99.22% *(98.95%)* of synop reported P_{msl} ($P_{msl-rep}$) observations passed the background check and 97.59% *(98.20%)* passed the final check. Whereas Table 1(b) shows that only 94.32% *(94.03%)* of reports of synop P_{msl} calculated from station level pressure ($P_{msl-stn}$) passed the background check and only 86.32% *(87.49%)* passed overall. The $P_{msl-stn}$ reports accounted for 18% of synop pressures, consisting mostly of those stations above 500m, since $P_{msl-rep}$ is used in preference below 500m; the higher flagging rate for $P_{msl-stn}$ was probably due to both poorer background fields near high orography and to poorer quality observations (possibly due to inaccurate station heights). All of the prior rejects of synop P passed the background check, indicating that their o-b biasses must be quite small. The 'other' flags are where the differences from background of P_{msl} and P^* disagree - mainly a few high level stations.

Table 1(c) shows that 97.91% *(96.82%)* of ship pressures passed the background check and 95.96% *(94.88%)* passed overall. The proportion of ship pressures and winds (Table 1(e)) rejected by CFO that would have been flagged anyway, was lower for October 1993 (1/3 and 1/5, respectively) than for October 1992 *(both 2/3)*.

The percentage of drifting buoy pressures that passed the background check in October 1993, 98.32%, was slightly up from the percentage in October 1992 *(97.31%)*. Although the percentage with a final flag, 32.39%, was also up on 1992 *(19.17%)*, due to an increase in 'prior' flags - largely composed of "thinned" drifters.

Table 1. Contingency tables of quality control decisions for surface observations in October 1993.

(a) Synop $P_{msl-rep}$ (445048 obs)

Background	Prior	CFO	Buddy	Other	Pass	
Pass	0.70	0.01	0.39	0.70	97.43	99.22
Fail	0.00	0.00	0.54	0.07	0.17	0.78
	0.70	0.01	0.92	0.78	97.59	100.00%

(b) Synop $P_{msl-stn}$ (97998 obs)

Background	Prior	CFO	Buddy	Other	Pass	
Pass	4.99	0.00	3.33	0.09	85.91	94.32
Fail	0.00	0.00	3.93	1.34	0.41	5.68
	4.99	0.00	7.26	1.43	86.32	100.00%

(c) Ship P_{msl} (79432 obs)

Background	Prior	CFO	Buddy	Other	Pass	
Pass	0.45	0.65	0.94	0.00	95.87	97.91
Fail	0.13	0.30	1.40	0.16	0.09	2.09
	0.58	0.96	2.34	0.16	95.96	100.00%

(d) Drifter P_{msl} (55845 obs)

Background	Prior	CFO	Buddy	Other	Pass	
Pass	30.54	0.00	0.22	0.00	67.55	98.32
Fail	0.33	0.00	1.18	0.11	0.06	1.68
	30.88	0.00	1.40	0.11	67.61	100.00%

(e) Ship wind (78981 obs)

Background	Prior	CFO	Buddy	Other	Pass	
Pass	2.93	0.38	0.19	0.00	93.98	97.48
Fail	0.13	0.10	2.12	0.03	0.14	2.52
	3.06	0.48	2.31	0.03	94.12	100.00%

In October 1993, as in the previous two Octobers, the buddy check rejected more pressure observations than it reinstated, e.g. for synop $P_{msl-stn}$ reports, 3.33% rejected and only 0.41% reinstated.

Table 1(e) shows that the percentage of ship winds that failed the background check fell for the 2nd year in succession, from 3.1% in 1992 to 2.5% in 1993. The buddy checking of ship winds affected a smaller percentage of observations than it did for pressures, with only a slightly larger percentage flagged than reinstated. Of the prior rejects, ~96% passed the background check, suggesting that some of these should not have been on the

permanent rejection list.

3.2 Aircraft

Table 2 shows the flagging for Airep and Asdar winds and temperatures for October 1993. Comparing (a) with (b) and (c) with (d), the better quality of the automated Asdar reports can clearly be seen, with only 0.10% *(0.10%)* and 0.13% *(0.16%)* of Asdar winds and temperatures, respectively, flagged by the background check. These compare with values of 0.87% and 0.97% for Aireps; although these values have more than halved from October 1992 *(1.81% and 2.14%)*, probably due to the removal of Carswell data.

Table 2. Contingency tables of quality control decisions for aircraft observations in October 1993.

(a) Airep winds (102007 obs)

Background	Prior	CFO	Buddy	Calm	Other	Pass	
Pass	6.96	0.72	0.26	0.71	2.32	88.16	99.13
Fail	0.00	0.30	0.48	0.00	0.00	0.09	0.87
	6.96	1.01	0.74	0.71	2.32	88.25	100.00%

(b) Asdar winds (95276 obs)

Background	Prior	CFO	Buddy	Calm	Other	Pass	
Pass	31.17	0.02	0.12	0.16	0.02	68.41	99.90
Fail	0.00	0.00	0.04	0.00	0.00	0.05	0.10
	31.17	0.02	0.17	0.16	0.02	68.46	100.00%

(c) Airep temperatures (102101 obs)

Background	Prior	CFO	Buddy	Other	Pass	
Pass	6.93	0.49	0.22	2.34	89.05	99.03
Fail	0.00	0.18	0.71	0.03	0.06	0.97
	6.93	0.67	0.93	2.37	89.10	100.00%

(d) Asdar temperatures (100825 obs)

Background	Prior	CFO	Buddy	Other	Pass	
Pass	29.52	0.01	0.10	0.02	70.21	99.87
Fail	0.00	0.01	0.08	0.00	0.04	0.13
	29.52	0.02	0.18	0.02	70.25	100.00%

The number of Aireps with prior flags (reports from aircraft on a blacklist of known poor quality observations) was little changed from October 1992. But the ~30% of Asdars with prior flags compares with none in 1992. This large increase was due to the change on 7th September to flag Asdar reports that were also

received as Amdars (Amdars are stored in the MDB and not looked at in this report).

As in October 1992, the buddy check still rejected more aircraft observations than it reinstated - nearly 3 times more: 0.26% cf 0.09% for Airep winds, 0.12% cf 0.05% for Asdar winds, 0.22% cf 0.06% for Airep temperatures and 0.10% cf 0.04% for Asdar temperatures.

Only just over 1/4 of the aircraft reports flagged by CFO would have been flagged by the background check anyway, compared to about 2/3 in October 1992. Of the 4101 *(5996)* wind and 175 *(138)* temperature reports supported by CFO, 1.0% *(0.7%)* of the winds were still flagged by the background check, but only one of the temperature reports was flagged.

Calms accounted for 0.71% *(0.47%)* of Aireps, compared to 0.16% *(0.23%)* of Asdars. Of the aircraft reports with permanent reject (prior) flags, none failed the background check, indicating that none were very bad. The 2.3% of Aireps and 0.02% of Asdars with 'other' flags are those that were flagged by the duplicate check.

3.3 Satellite cloud-track winds (Satobs)

Table 3 shows that the Satob-Satob buddy check continued to reinstate many times more observations than it rejected; and this was particularly so for Meteosat, which reinstated 0.22% *(0.22%)* and rejected less than 0.01%. The 3.5% that failed the background check was similar to the percentage for October 1992 *(3.28%)*. In October 1992 (and 1991) about 2/3 of CFO rejects would have failed the background check anyway, but in October 1993 all of the CFO rejects would have passed the background check.

Table 3. Contingency table of quality control decisions for satellite cloud-track winds in October 1993.

(233838 obs)		Prior	CFO	Buddy	Pass	
Background	Pass	16.90	0.15	0.01	79.40	96.47
	Fail	0.00	0.00	3.38	0.15	3.53
		16.90	0.15	3.39	79.55	100.00%

3.4 Bogus observations

Tables 4(a) and 4(b) show that very few surface bogus observations were flagged by the background check, only 0.02% *(0.43%)* of pressures and no winds at all *(0.29%)*. The 12% *(5%)* of winds with a prior flag are reports over model land points - all surface wind reports over land are permanently rejected. The buddy check with other surface observations (bogus observations do not buddy check each other) only resulted in 0.42% *(0.61%)* of bogus pressures being flagged and none *(0.29%)* were reinstated.

Table 4(c) shows that very few upper level bogus observations were flagged by the background check - no thicknesses, only 0.11% *(1.60%)* of winds, 0.17% *(0.31%)* of temperatures and 1.31% *(0.67%)* of humidities. [There is no buddy check for upper level bogus observations.]

Table 4. Contingency tables of quality control decisions for CFO bogus observations in October 1993.

(a) Bogus P_{msl} (6603 obs)

		Prior	Buddy	Pass	
Background	Pass	1.09	0.42	98.47	99.98
	Fail	0.00	0.02	0.00	0.02
		1.09	0.44	98.47	100.00%

(b) Bogus 10m wind (3490 obs)

		Prior	Buddy	Pass	
Background	Pass	12.18	0.00	87.82	100.00
	Fail	0.00	0.00	0.00	0.00
		12.18	0.00	87.82	100.00%

(c) Upper level bogus

	Number	Background Flag (%)	Pass (%)
Wind	1876	0.11	99.89
Temperature	588	0.17	99.83
Relative Hum.	1455	1.31	98.69
Thickness	543	0.00	100.00

The reduction in percentage of bogus winds, temperatures and pressures flagged in October 1993 compared to October 1992, was probably mostly due to the introduction on 1st December 1992 of a program to enhance BGEs near to bogus and supported observations (Parrett, 1992). The enhanced BGEs effectively relax the quality control in the region of these observations (and give the

observations more weight in the assimilation).

3.5 NESDIS 500km satellite soundings (Satems)

Figure 8 shows the number of Satems rejected in each layer during October 1993, and displays a very similar picture to that for October 1992 (Figure 9 in P93). About 85% of tropospheric layers (below 100hPa) and 53% of stratospheric layers had a prior reject flag. These flags are set for the whole sounding where it is co-located with a Sat120, and for tropospheric layers only for soundings over model land points. The bottom layer is also rejected north of 30°S, and the top Satem layer (7-3hPa) is permanently rejected, because background heights are not available for 3hPa.

Of the remaining Satems, ~23% failed the tropospheric stability check, which compares the stability of the sounding below 300hPa with that of the background. There were fewer stability flags in the bottom layer, indicating that the majority of these flags were in the northern hemisphere.

The multi-level check, which basicly rejects all layers above or below 100hPa if at least one of these layers is flagged or two layers are suspect (PGE > 0.3), rejected ~4.5% of stratospheric layers but very few tropospheric layers. Likely tropospheric layers would probably already have been flagged by the stability check. There are very few remaining layers that were rejected by the background check, except high in the stratosphere where a model temperature bias led to ~28% of the 10-7hPa layer being flagged. The layers next to the surface are flagged if they are suspect, as is the layer 100-70hPa if all layers below 100hPa are flagged; these account for the small number of 'other' flags.

3.6 Radiosondes

The number of radiosonde observations at each model level in October 1993 was approximately the same as in October 1992. The highest number was again at level 5 (~800hPa), at just above 61000, falling steadily to ~49000 at level 14 (~150hPa) and then falling off more rapidly to zero at level 19.

Figure 9 shows the percentages of sonde winds, temperatures and relative humidities rejected at each model level in October 1993. Less than 0.7% of sonde winds were flagged at any level (Figure 9(a)), which is slightly down on October 1992 when *~0.9%* were flagged between levels 10 and 12. This may represent an improvement, either in the model or the data, or it may just be indicative of different weather regimes over the data dense areas in the northern hemisphere in October 1993 compared to October 1992. Most of the permanent (prior) rejects were in the southern hemisphere, accounting for 2% of sonde winds south of 30°S. There were very few (if any) winds rejected by CFO. Most of the rejections were by the background check, although there were fewer than in October 1992. These peaked at level 11 (~300hPa) at 0.5% *(0.7%)* and accounted for at least 0.25% *(0.5%)* of winds between 500hPa and 150hPa, near the level of the jetstream. The remaining small percentage of flags were buddy check flags, which accounted for less than 0.02% *(0.03%)* of sonde winds at any level.

Figure 9(b) shows that there were more temperatures flagged than winds, but most were prior rejects, consisting mainly of Indian stations which are all permanently rejected. The majority of the remaining rejections were background flags, which peaked at level 1 (presumably due to boundary layer effects) and again at levels 16 and 17 in the stratosphere. Throughout most of the troposphere (above the boundary layer) only 0.1-0.3% of sonde temperatures were flagged by the background check, which is comparable to the 0.2-0.3% for October 1992. Only at level 1 were there more flags in October 1993 than in October 1992; this was due to the interpolation/extrapolation inconsistencies evident following the change on 6th July to use model level temperature fields while sonde levels below the model surface were still being used (until 9th November). There were very few buddy check flags - less than 0.05% at any level.

Figure 9(c) shows that there were few relative humidities rejected below about 600hPa (~0.5%) and most of these were background flags. Above 600hPa, the proportion of humidities with a prior flag increased steadily to 100% at ~200hPa; these are humidities with associated temperatures below -40°C, which are

given a permanent reject flag. There were ~0.7% of humidities flagged by the background check between about 500 and 300hPa.

4. Summary

The percentages of observations flagged by the quality control scheme mostly decreased slightly during 1993. This was due to both improvements in the model and better selection of reports to permanently reject (at the observation processing stage).

The flagging of surface data in 1993 was little changed from 1992, with just a small reduction in flags generally. Most of the changes in the flagging of aircraft data were due to changes in the list of permanent rejects and to changes in the extraction of data, in particular the removal of Carswell data in September. The introduction of synoptic-dependent BGEs on 16th November resulted in a small reduction in flags of Airep winds and upper level sonde winds, counteracting to some extent the trend for the percentage of flagged winds to increase in the northern hemisphere winter (associated with the stronger winds).

The model improvements associated with the introduction of UM versions 3.0 and 3.1 generally led to small reductions in the percentage of sondes that were flagged. The removal of sonde levels below the model surface (on 9th November) removed a source of spurious data caused by inconsistencies in the vertical interpolation/extrapolation and reduced the flagging rate of low level sonde temperatures.

The effectiveness of intervention by forecasters in the CFO during 1993 seems to have generally improved from 1992, despite (or because of?) a reduction in the amount of intervention due to removal of one of the two intervention rostas. There were fewer unnecessary rejections by CFO and less flagging of their bogus observations. The latter was partly due to the enhancement of BGEs near to bogus and supported observations, introduced in December 1992. The diminished duplication of rejections (CFO and background) may be due to more rejections being in the same areas as bogus and supported observations (where the BGEs are higher and the QC is relaxed somewhat).

5. References

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The ASDAR centre, Observation Provision Division.

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The ASDAR centre, Observation Provision Division.

Acknowledgements

Thanks are due to Bruce Ingleby for most of the original SAS programs, some useful comments and for supplying Appendix B.

Appendix A - Operational changes and incidents that may have affected the flagging of observations

11th-13th Jan SURFACE: no Drifters from USA 18Z 11th - 06Z 13th.

12th Jan SONDE: gross climatological checks introduced into observation processing, and error corrected;
reposition bogus scheme extended to N.Atlantic.

SURFACE: rejection/correction list updated for ship and drifter pressures and winds;
reposition bogus scheme extended to be global;
correction to assignment of BGEs (LAM and MES only).

SAT120: ceased to flag whole sounding when troposphere flagged.

1st-28th Feb SATEM: OPD data lost for whole of February.

2nd Feb AIRCRAFT: rejection list updated - all airlines removed, except WA;
track check introduced and duplicate check improved.

SATOB: rejection list updated to reject the following - all GMS above 500hPa and outside 20N-20S, and all Meteosat and GOES above 500hPa over land and outside of 20N-20S;
extraction corrected - more Satobs for update runs.

5th Feb UM: ∇^4 diffusion introduced at levels 18 and 19 to prevent instabilities.

16th Feb SURFACE: rejection/correction list updated.

17th-26th Feb SURFACE: GTS problems with Drifters.

23rd Feb UM: version 3.0 introduced - new orography on changed land/sea mask and new ozone file.

1st-9th Mar SAT120: no data received - NESDIS changing processors.

2nd Mar SONDE: re-introduced -40°C cut-off for rejection of humidity data.

9th Mar SURFACE: rejection/correction list updated.

AIRCRAFT: Aireps bound for ECMWF also sent to SDB - many duplicates;
some Asdars lost 9th-14th.

UM: version 3.0+ introduced - gravity wave drag code corrected, horizontal diffusion of humidity changed from 2nd to 4th order (some jets stronger), and vertical advection corrected.

10th-11th Mar SONDE/SURFACE: SDB problem - many reports with missing latitude, longitude or height.

15th Mar UM: further correction to gravity wave drag - standard deviation of orography reconfigured.

16th Mar AIRCRAFT: catered for more reports in obs processing.

23rd Mar AIRCRAFT: Asdar CO00624Z added to rejection list

(faulty - switched-off on 2nd April).

30th Mar SURFACE: correction to background check of humidity.

6th Apr SURFACE: rejection/correction list updated.

10th-14th Apr SURFACE: no drifters from USA 00z 10th - 06Z 14th.

16th-19th Apr SURFACE: no drifters from Toulouse 18Z/16-00Z/19.

20th Apr Preliminary runs of automatic QC introduced.

4th May SONDE: reports extracted hourly (new version of routine UAQC), resulting in up to 20 more sondes being used.

ALL: flags set on all elements when whole report flagged (no change in obs used in assimilation);

AIRCRAFT: maximum speed in track check increased from 2000km/hr to 2300 km/hr (to not flag some Concorde reports).

SATEM/SAT120: extraction and obs processing changed; quality control re-arranged to reduce CP time.

11th May SURFACE: rejection/correction list updated.

13th-15th May SURFACE: few drifters from USA.

25th May UM: version 3.1 introduced - included a change to the vertical interpolation of temperature to reduce the warm bias in the stratosphere.

1st-30th Jun SONDE: no corrected sondes received from USA.

8th Jun AIRCRAFT: rejection list updated - rejected cruise level temperature from PH012** and rejected all XX999 (including some Pireps recoded as Aireps).

SURFACE: rejection/correction list updated.

23rd-24th Jun SURFACE: only 60-70% of drifters received.

6th Jul SONDE/AIRCRAFT/SATOB: model level background fields used instead of pressure level fields in vertical interpolation to observation levels;

SONDE: humidity rejected if station is on permanent rejection list for temperature;
sondes with no data flagged as 'unusable'.

13th Jul SURFACE: rejection/correction list updated.

18th Jul AIRCRAFT: increase in number of Aireps due to recoding of Asdars.

3rd Aug SONDE: minor change to the treatment of gaps in the vertical averaging, within the quality control.

AIRCRAFT: reduction in observation errors for Airep winds and for Asdar winds and temperatures (largest reductions below cruise levels) - see UMDP 32 Appendix 1 for details.

SONDE/SURFACE: correction to correlation scales for buddy check (LAM and MES only).

SCATTEROMETER WINDS: included in global assimilation.

3rd,6th,8th,21st Aug ALL data: some OPD data missing - operational problems.

10th Aug SURFACE: rejection/correction list updated.

18th-26th Aug UM: instabilities at T+0 at level 19, associated with a 'whirlpool' between S. Africa, Australia and New Zealand - removed by bogussing.

27th Aug AIRCRAFT: no Aireps due to operational problem.

6th Sep UM: another 'whirlpool', removed by bogussing.

7th Sep AIRCRAFT: Amdars extracted from the MDB, and duplicate Aireps from the SDB flagged;
rejection list updated.

SONDE: correction to processing of bogus thickness obs.

SONDE/SURFACE: Synop and sonde station details retrieved from MDB and flagged if no station height reported.

10th Sep ALL: OPD data lost - operational problem.

13th Sep AIRCRAFT: Carswell reports no longer stored (majority were either duplicates or had wrong locations).

14th Sep SURFACE: rejection/correction list updated.

27th-28th Sep SAT120: extra, corrupt Sat120 data - switched-off in assimilation until problem resolved on 28th.

28th Sep ACOBS: format of ACOBS files changed.

5th Oct SURFACE: correction to flag ships with SDB land flags.

SONDE: correction to vertical averaging - check for missing data in o-b.

AIRCRAFT: corrections to duplicate check and intervention.

12th Oct SURFACE: rejection/correction list updated.

13th-15th Oct SAT120: switched-off, because of failures due to data limit being exceeded in obs processing step.

16th-18th Oct SATEM: no data.

19th Oct UM: version 3.2 implemented.

26th Oct SONDE: OPD changed to receive standard level Pilot winds.

2nd Nov SURFACE: winds from moored buoys and plats/rigs given different model obs types to ship winds.

3rd Nov SATOB: change to code form, caused problems in OPD - Meteosat water vapour data included with infra-red data (for most of Nov), some GOES data with wrong id, and most of GMS data missing.

9th Nov SURFACE: assimilation of winds from moored buoys, platforms and rigs (at model level 1, ~25m) switched-off temporarily for 1 week;
rejection/correction list updated;
temperature and humidity buddy check switched-on and buddy check search radius reduced to 200km (MES only).

SONDE: reported levels below the model surface rejected;

PILOT heights converted to pressures using model background fields.

AIRCRAFT: all automatic reports extracted and returned to the MDB;
track and duplicate checks applied to automatic data; rejection list updated.

SATEM: change to extraction and obs processing (data volume limit).

16th Nov ALL: synoptic-dependent BGEs introduced for upper winds and temperatures;
associated changes included tuning of assimilation, and reduced observation error, PGE0 and tophat function for sonde and aircraft winds.

SURFACE: assimilation of winds from moored buoys, platforms and rigs switched-on again, but at 10m now (their nominal observation height).

29th Nov UM: calculation of tropopause height corrected.

2nd and 5th Dec SATEM/SAT120: occasional failures in obs processing and data not used.

5th-9th Dec UM: large temperature biasses at levels 18 and 19 at T+0 over N. Atlantic, due to error in analysis causing feedback.

7th Dec SURFACE: rejection/correction list updated.

30th and 31st Dec SATEM/SAT120: all runs of obs processing failed and data not used.

Appendix B - Introduction of a radiosonde-aircraft buddy check on 8th February 1994

After preliminary tuning, the radiosonde-airep buddy check was tested on eight cases, the average results are given in Table B1. On these cases there was a slight increase in the flagging of radiosonde temperatures and a slight decrease for radiosonde winds and AMDAR winds and temperatures. (AMDAR is taken to include all aircraft received in binary code form, figures for manually transmitted AIREPs have not been included as they were not subject to any changed decisions.)

	Number:	Reported	Flagged - control	Flagged - test
Radiosonde	Temp.	8663	30.1 (0.35%)	31.1 (0.36%)
	Wind	10119	20.1 (0.20%)	19.2 (0.19%)
AMDAR	Temp.	3514	18.9 (0.53%)	17.5 (0.50%)
	Wind	3483	18.0 (0.52%)	17.3 (0.50%)

Table B1. Average numbers of observation levels without prior rejects, and those flagged in the control and test (radiosonde-aircraft buddy check). Average over eight cases: 00Z 5th Oct 1993, 00Z 6th Dec 1993, 00Z 21st Dec 1993, 12Z 21st Dec 1993, 12Z 8th Jan 1994, 12Z 10th Jan 1994, 00Z 11th Jan 1994 and 00Z 12th Jan 1994.

The effect was not spread evenly over the cases (which were chosen at random except for the 5th Oct 1993 case). Some aspects of four cases will be described in greater detail.

00Z 5th October 1993

This case was noted by K Wright and M Pickup of CFO and formed the impetus for work on a radiosonde-aircraft buddy check. Two Australian radiosondes 94791 and 94578 had two and four levels of wind rejected respectively, despite the presence of corroborating aircraft data.

For this study the observations had to be re-extracted and the background forecast rerun. This resulted in minor differences: 94791 and 94578 each had one less level flagged. (No intervention could be applied, and slightly later versions of the forecast model and quality control were used, including synoptic dependent background errors in the upper atmosphere.) **The test run, buddy checking against aircraft data, reprieved one level from 94791, two from 94578 and four from other Australian radiosondes.**

One reason identified for the flagging of the radiosonde winds was that none of the Australian reports included their maximum wind level. The SDB interpolation check then flagged several standard levels in the vicinity, making it more likely that the quality control would reject the observations. A quick test was run in which the SDB flags were ignored; this was even more effective than the buddy check against aircraft data in passing the Australian winds. However this is not a satisfactory solution, and the Australians are looking at changing their reporting practice (following a message from A Radford they realised that their maximum winds were only being stored in a national section of the TEMP code, which was being stripped out prior to transmission on the GTS).

12Z 6 December 1993

On this case nine extra aircraft temperatures, all from AN0093 passed the quality control, they were all below 880 hPa and came from a descent and an ascent. They were between 7.2 and 8.7 degrees colder than background, but agreed well with radiosonde 94326 nearby (which had a level reprieved).

00Z 21st December 1993

Radisonde 72456 had a wind of 337°/90 knots at 247 hPa flagged by the change (background was 305/74). The aircraft in the vicinity were reporting directions between 293 and 308, so it appears that the radiosonde was about 30° wrong. Temperatures at about 195 hPa from 72562 and 72654 were rejected, their differences from background were 3.3° (with an SDB flag) and 4.1° respectively, subjectively these were considered to be borderline given the somewhat variable nearby aircraft temperatures. Australian radiosonde 94672 had a wind at 786 hPa reinstated correctly.

00Z 12th January 1994

This case featured 8 aircraft temperatures reprieved and 7 extra flagged. Four identical reports from BA000NEZ were reprieved (three of them should have been rejected by the duplicate check). At cruise levels over the US two reports were reprieved and two flagged. At low levels over Melbourne three reports were reprieved (at 2215Z, 8° colder than background), four were flagged (between 0136Z and 0257Z and 4° to 7° warmer than background). There were many more reports that passed the quality control in both runs, indicating that the temperature did indeed rise by over 12° in five hours below 950 hPa.

Distribution of changes

Table B2 gives the horizontal and vertical distribution of the changes. There were more changes over Australia than the US, particularly for radiosondes (although if the 5th Oct case is excluded the distribution is almost even). For radiosondes there were more high level changes, and for AMDARs more low level changes: the numbers are dominated by the first two cases detailed above.

	Horizontal			Vertical	
	Australia	US	Other	Low	High
sonde	14	8	1	7	16
AMDAR	29	23	0	37	15

Table B2. Horizontal and vertical distribution of changed decisions. Low (high) level is taken to be below (above) 500 hPa.

Implementation

Given the improvement on the case reported by CFO, and the generally slightly positive or neutral effect on other cases it was decided to implement the radiosonde-aircraft buddy check with effect from 8th February 1994. As can be seen from table B1 the average effect is likely to be rather small.

Figure 1.

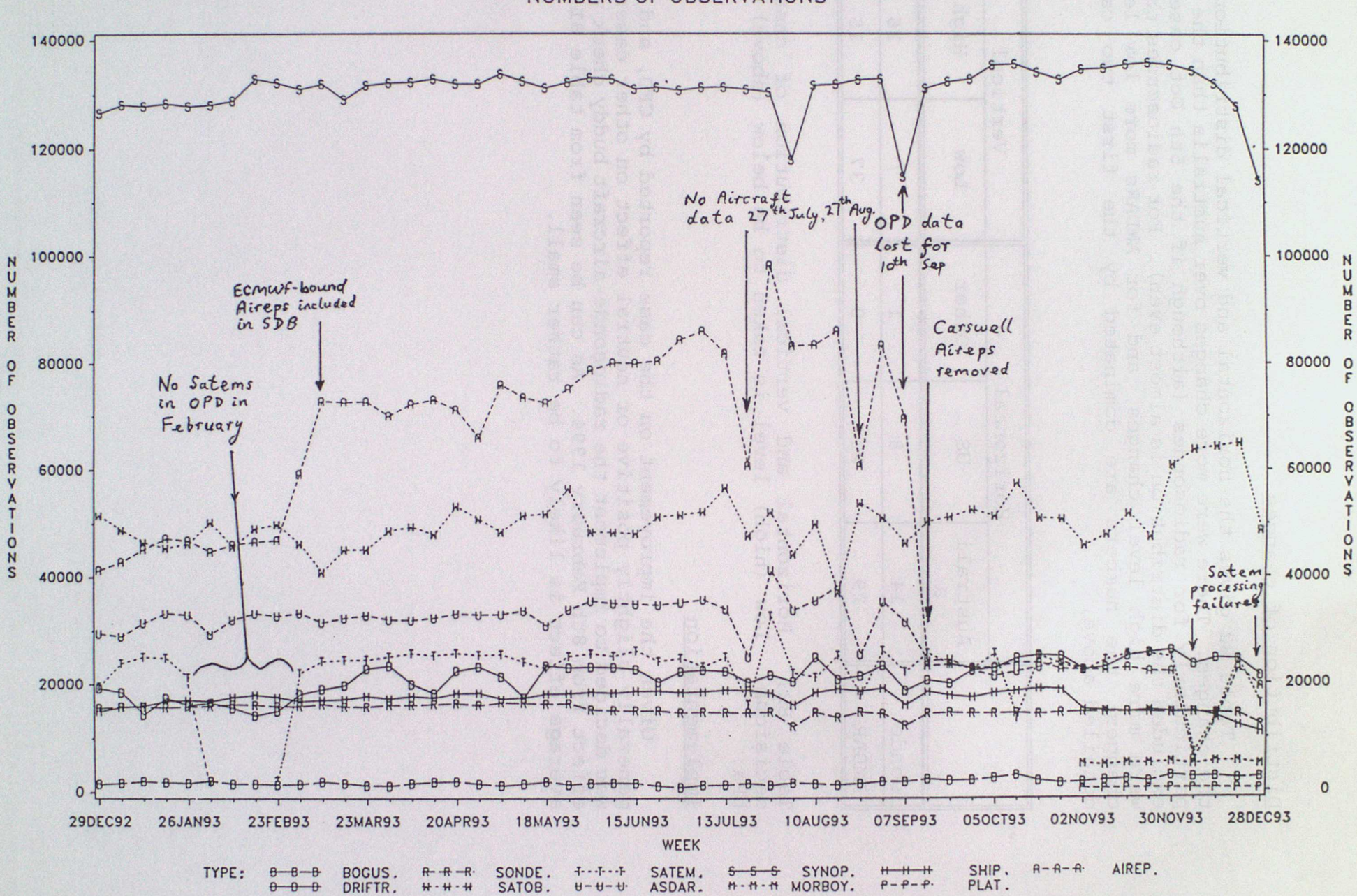

NUMBERS OF OBSERVATIONS
NUMBER OF OBSERVATIONS
NUMBER OF OBSERVATIONS
140000
120000
100000
80000
60000
40000
20000
0
No Satems in OPD in February
ECMWF-bound Aireps included in SDB
No Aircraft data 27th July, 27th Aug.
OPD data lost for 10th Sep
Carswell Aireps removed
Satem processing failures
29DEC92
26JAN93
23FEB93
23MAR93
20APR93
18MAY93
15JUN93
13JUL93
10AUG93
07SEP93
05OCT93
02NOV93
30NOV93
28DEC93
WEEK
TYPE:
BOGUS.
DRIFTR.
SONDE.
SATOB.
SATEM.
ASDAR.
SYNOP.
MORBOY.
SHIP.
PLAT.
AIREP.

Figure 2 (a)

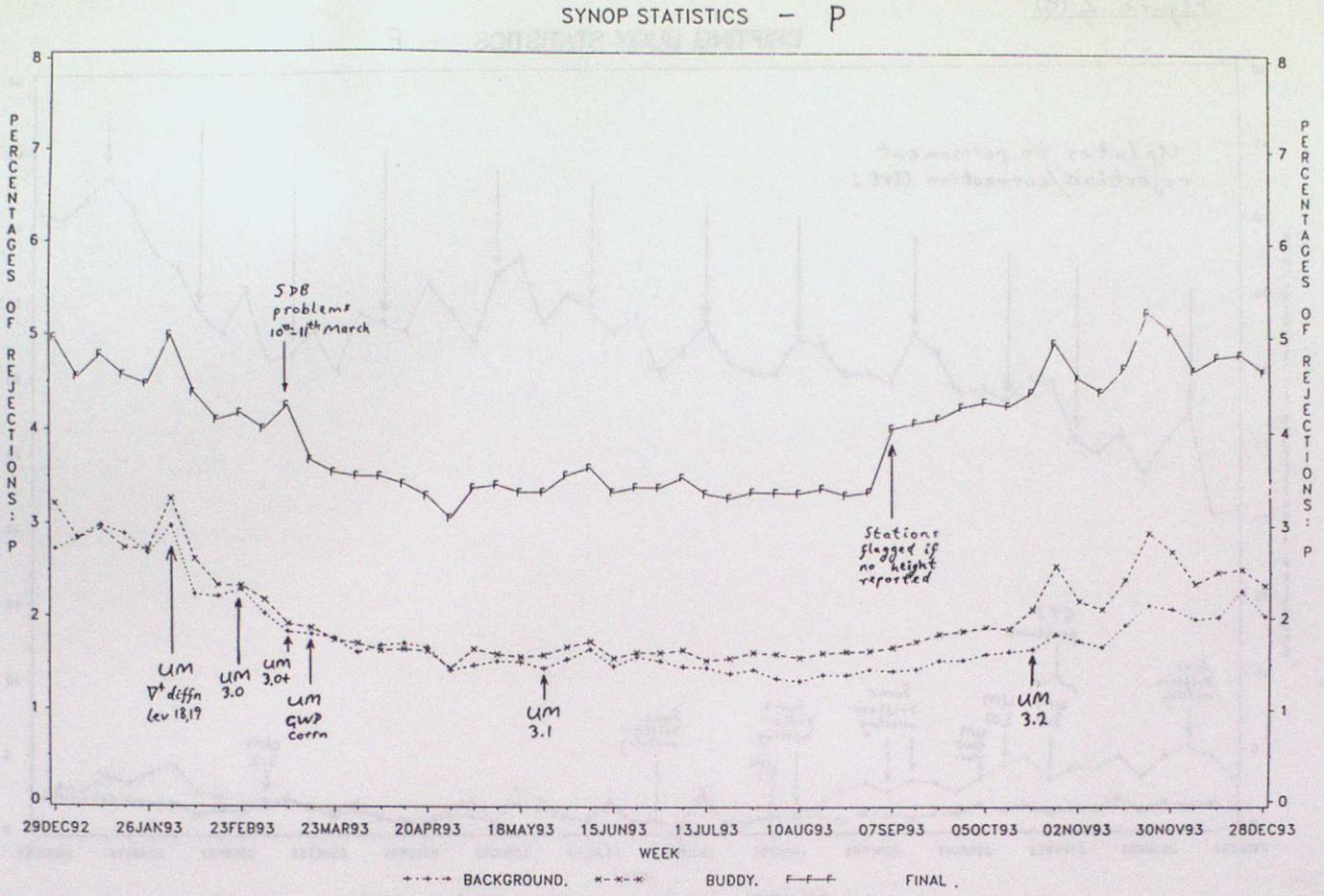


Figure 2 (b)

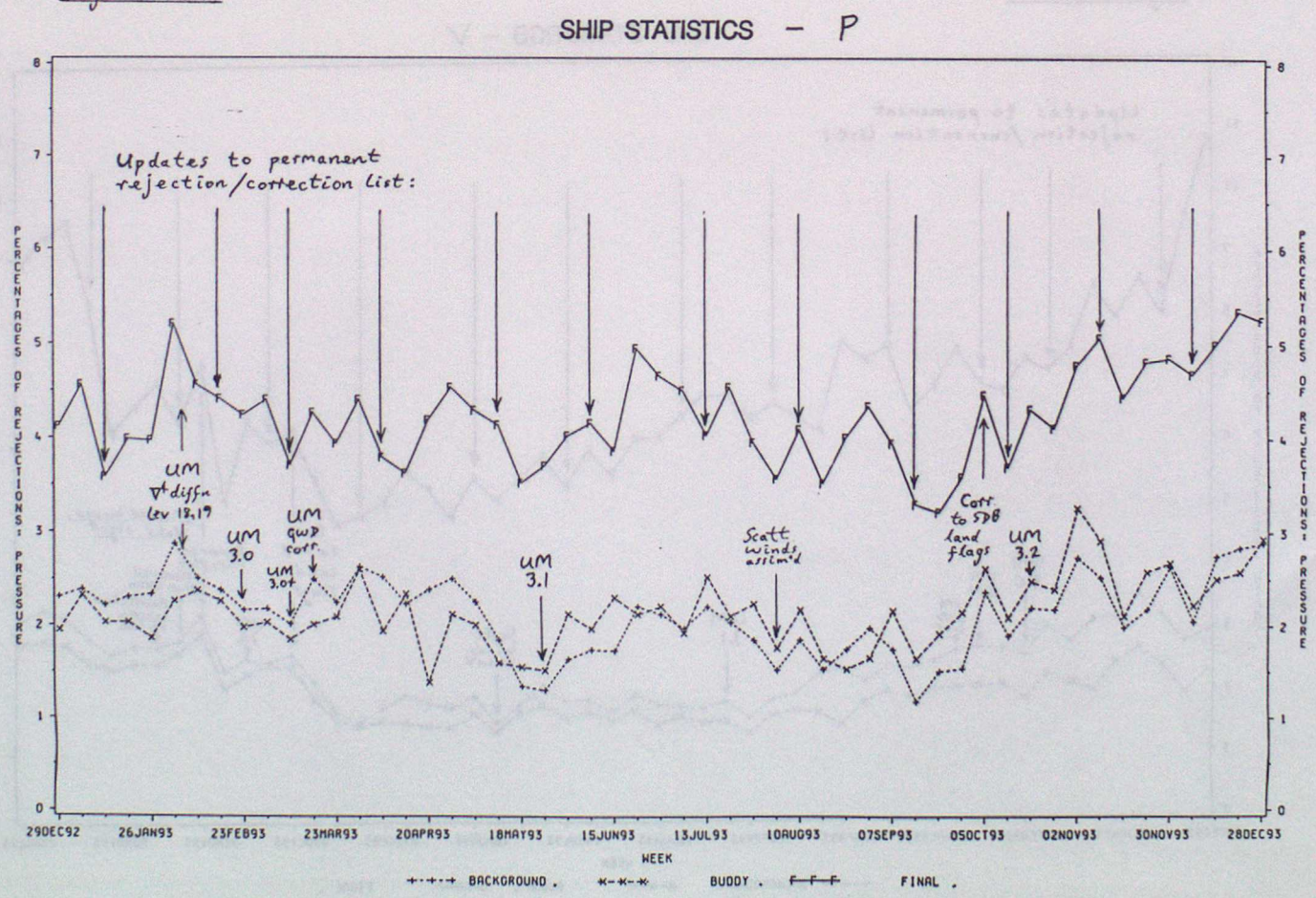


Figure 2 (c)

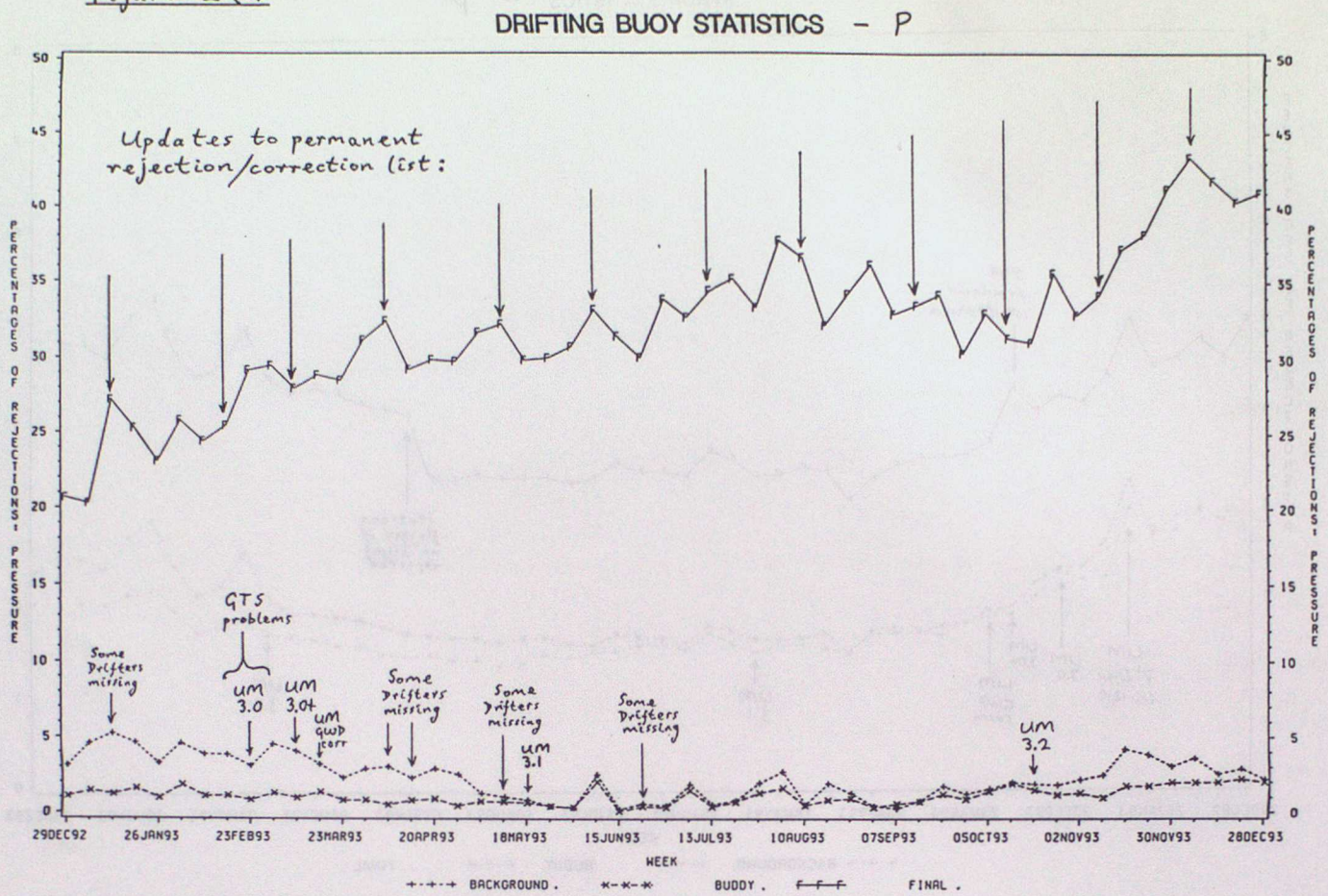


Figure 2 (d)

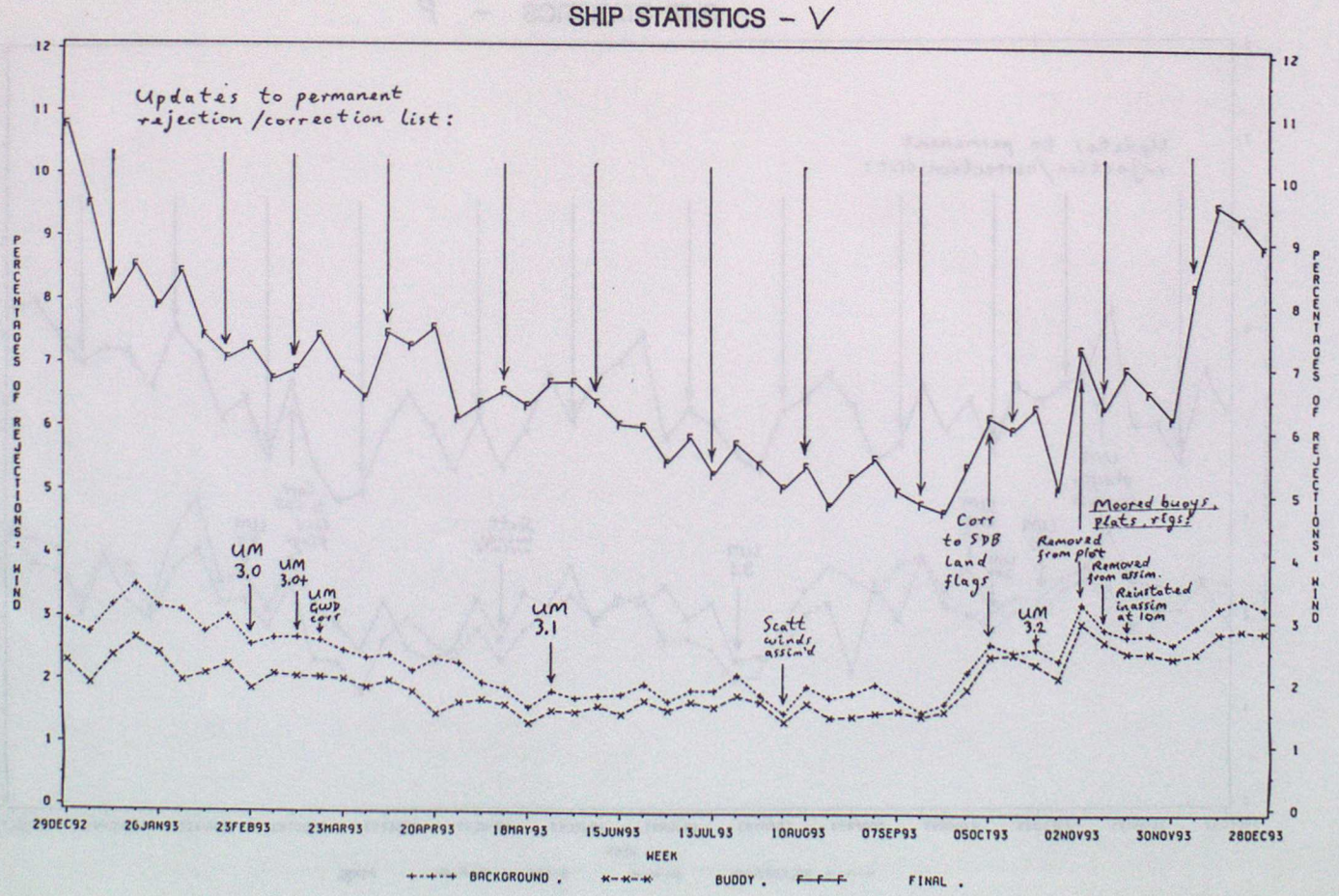


Figure 3 (a)

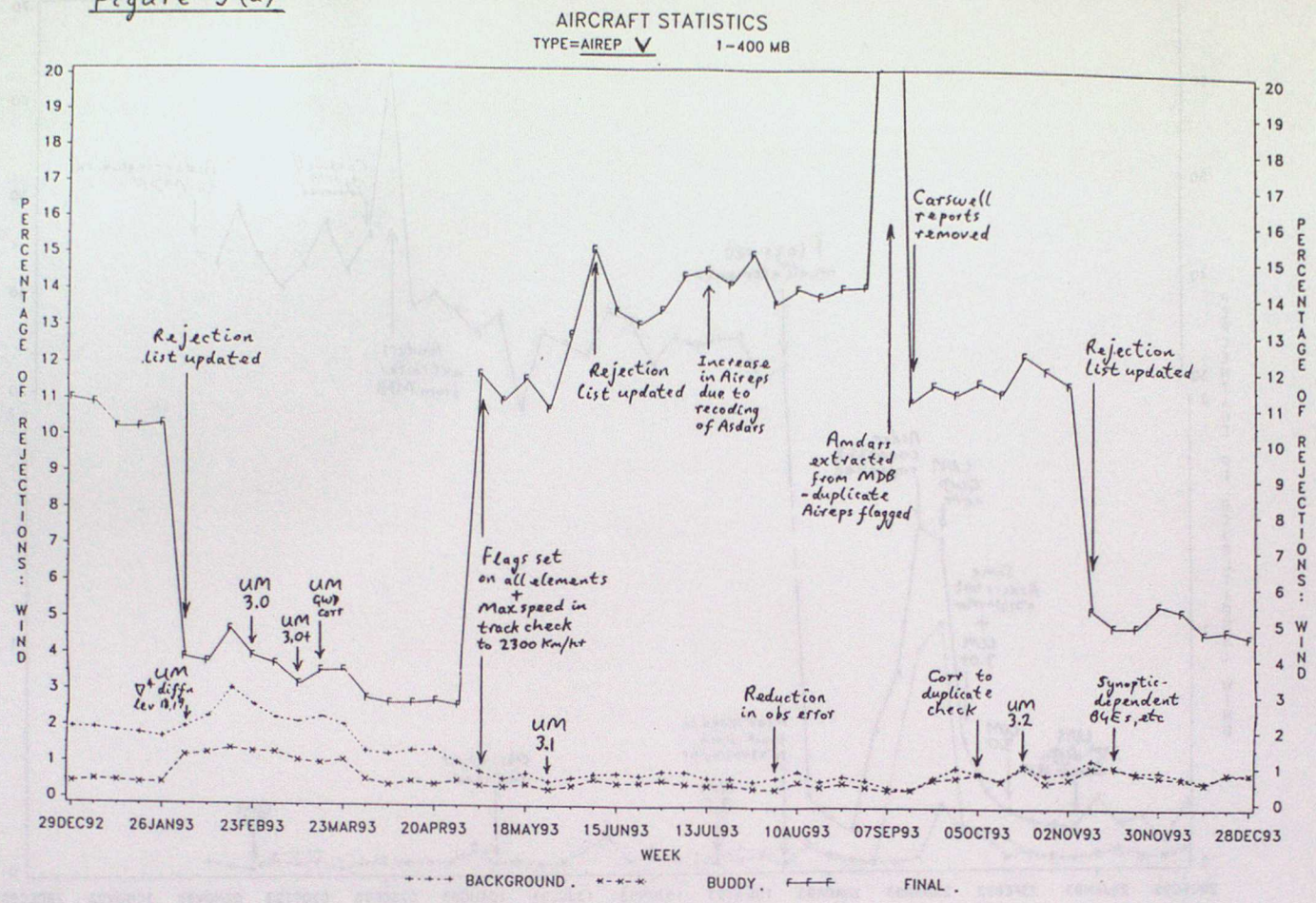
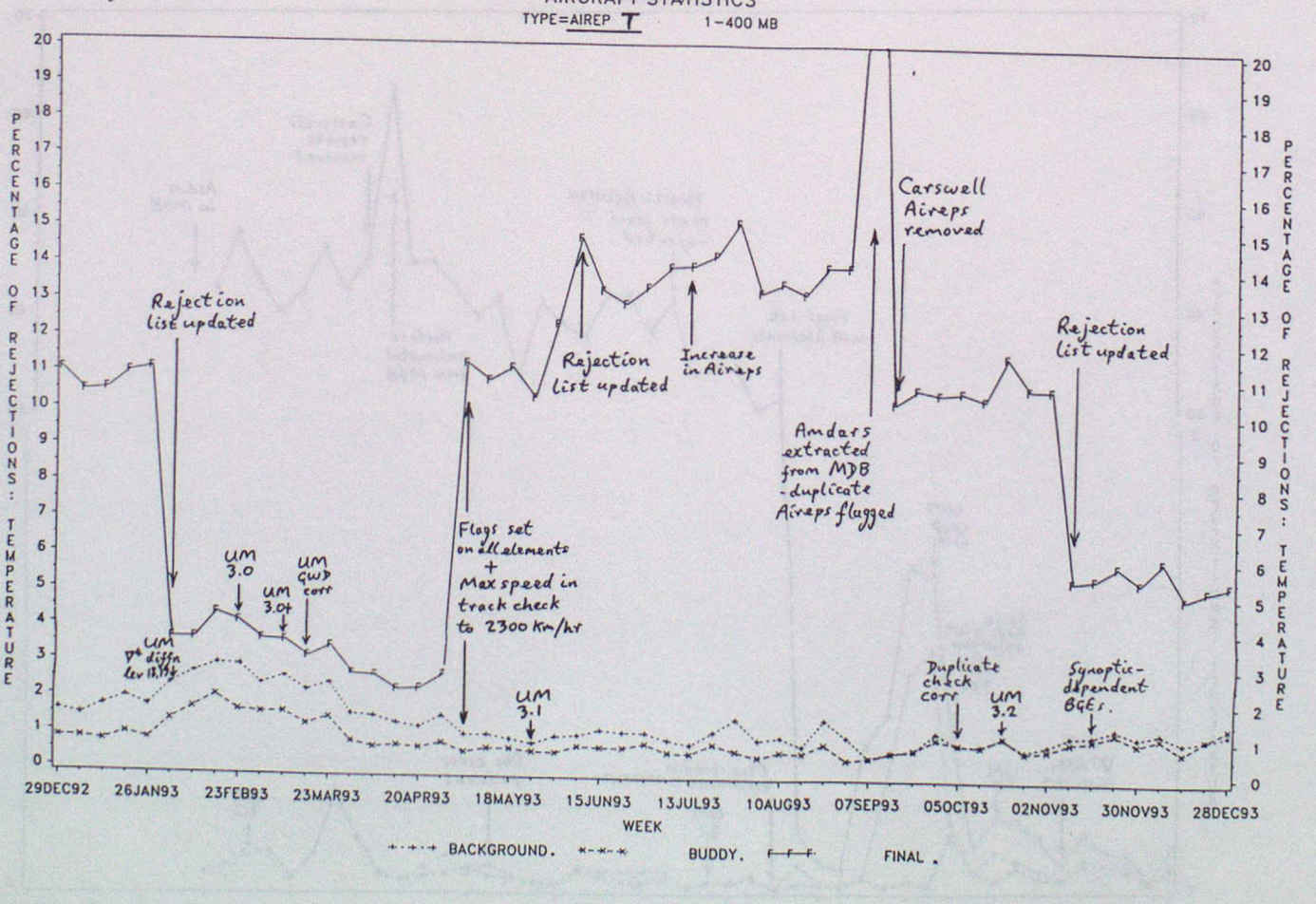


Figure 3 (b)



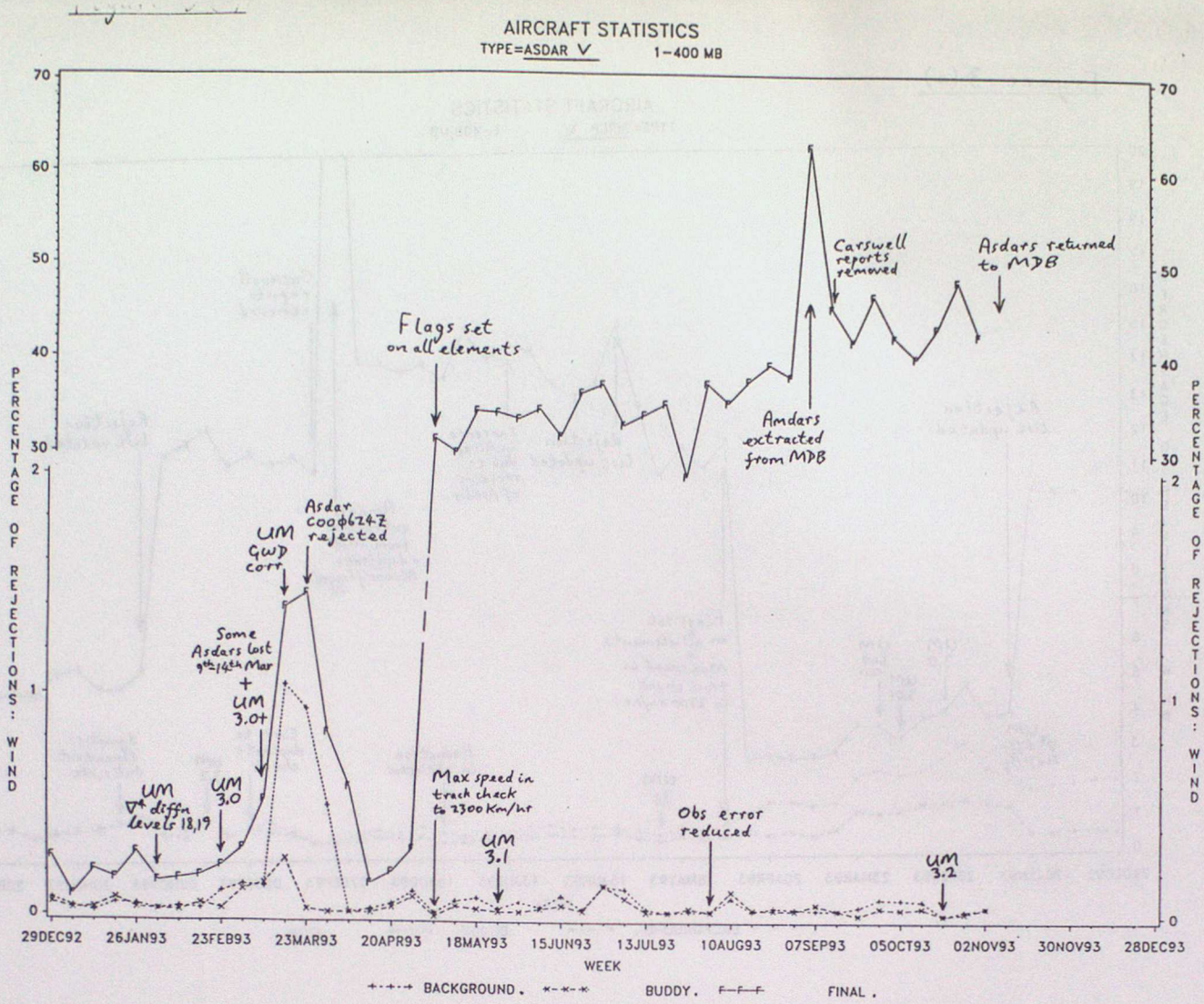

AIRCRAFT STATISTICS
TYPE=ASDAR V
1-400 MB
PERCENTAGE OF REJECTIONS: WIND
Flags set on all elements
Carswell reports removed
Asdars returned to MDB
Amdars extracted from MDB
UM GWD corr
Asdar C00$674Z rejected
Some Asdars lost 9th/14th Mar
+ UM 3.0t
UM 3.0
UM ∇⁴ diffn levels 18,19
Max speed in track check to 2300 Km/hr
UM 3.1
Obs error reduced
UM 3.2
29DEC92
26JAN93
23FEB93
23MAR93
20APR93
18MAY93
15JUN93
13JUL93
10AUG93
07SEP93
05OCT93
02NOV93
30NOV93
28DEC93
WEEK
BACKGROUND.
BUDDY.
FINAL.

Figure 3(d)

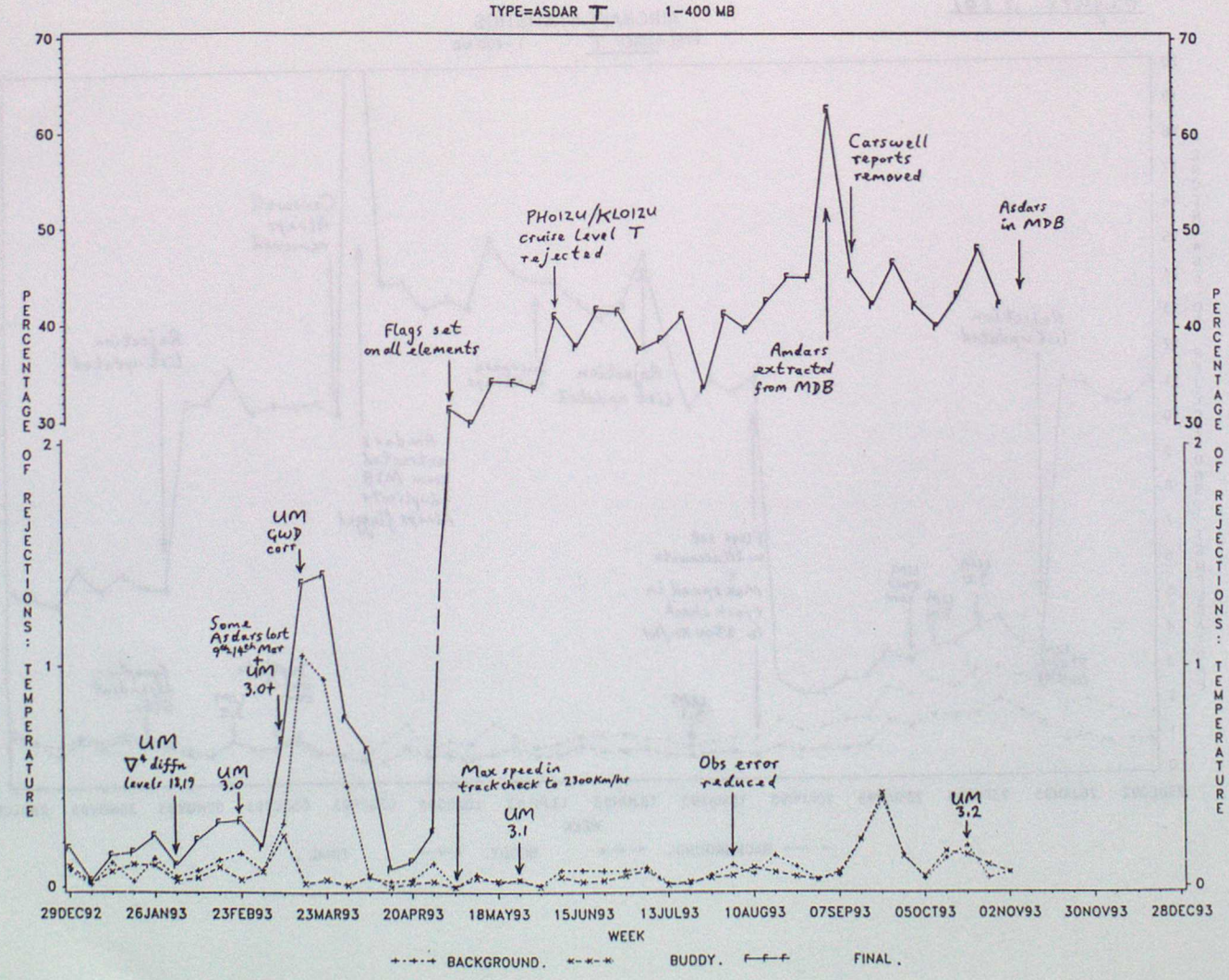

AIRCRAFT STATISTICS
TYPE=ASDAR T
1-400 MB
PERCENTAGE OF REJECTIONS: TEMPERATURE
Carswell reports removed
Asdars in MDB
PH012U/KL012U cruise level T rejected
Flags set on all elements
Amdars extracted from MDB
UM GWD corr
Some Asdars lost 9th/14th Mar
+ UM 3.0t
UM 3.0
UM ∇⁴ diffn levels 13,19
Max speed in track check to 2300Km/hr
UM 3.1
Obs error reduced
UM 3.2
29DEC92
26JAN93
23FEB93
23MAR93
20APR93
18MAY93
15JUN93
13JUL93
10AUG93
07SEP93
05OCT93
02NOV93
30NOV93
28DEC93
WEEK
BACKGROUND.
BUDDY.
FINAL.

Figure 4 (a)

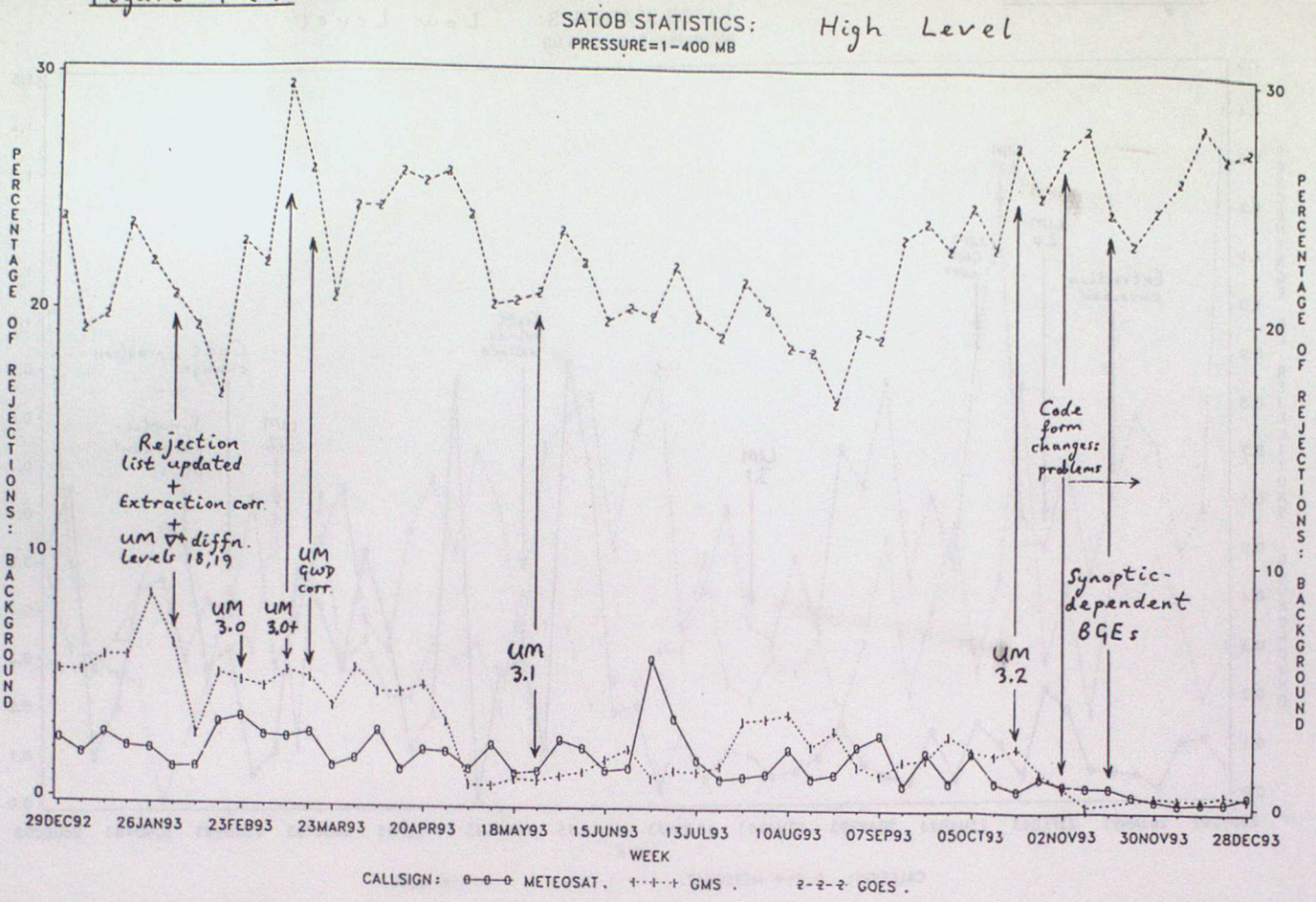


Figure 4 (b)

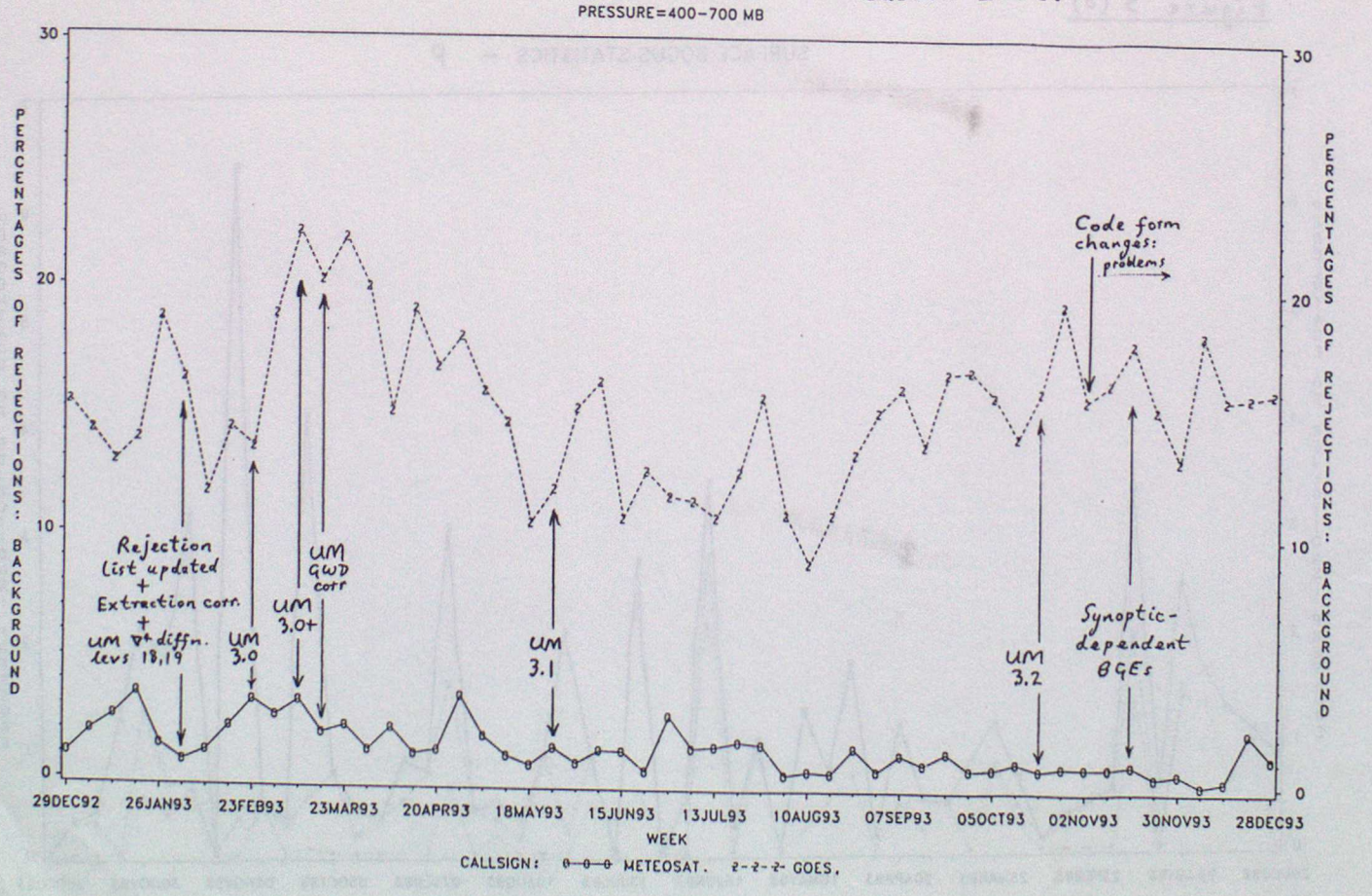


Figure 4 (c)

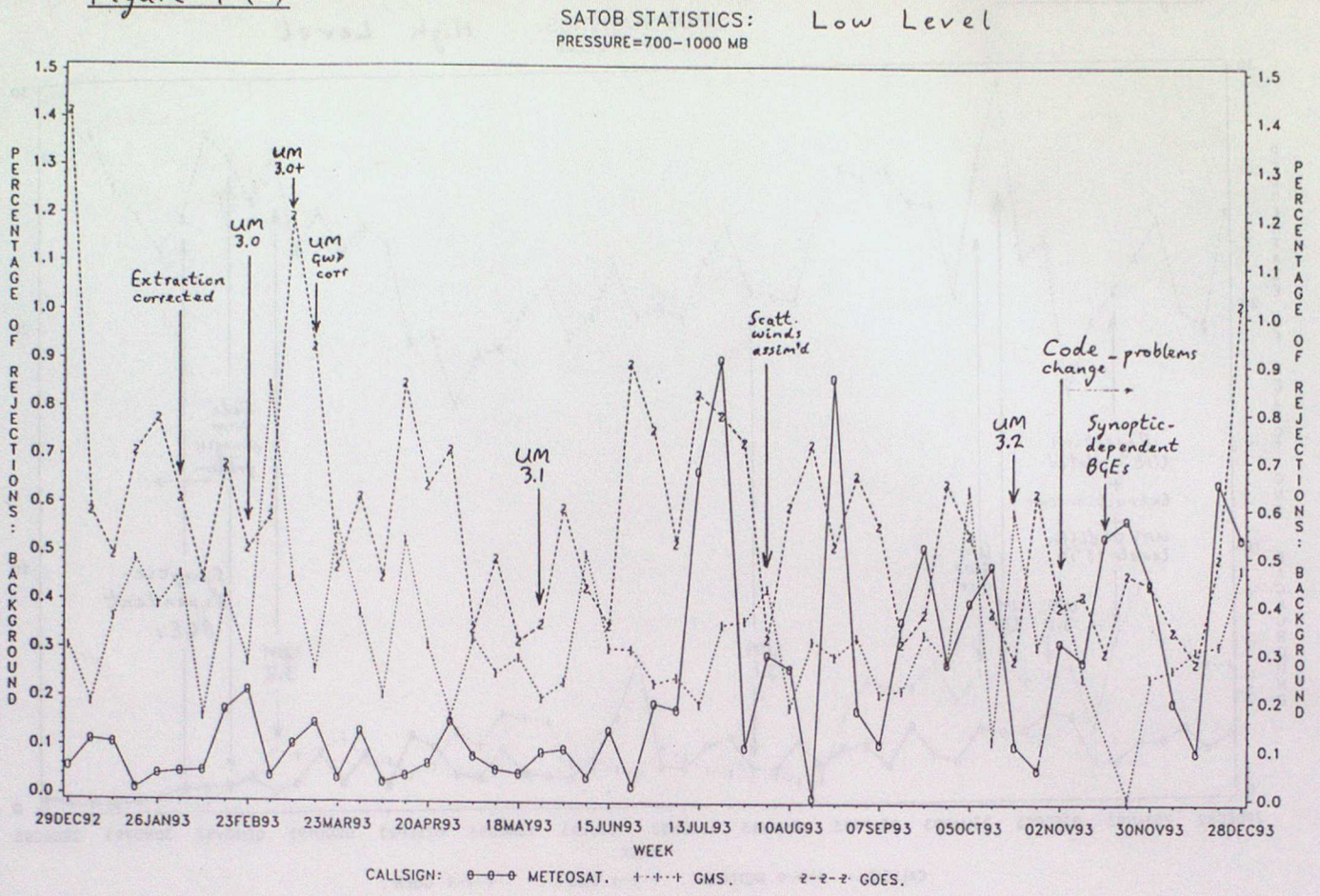


Figure 5 (a)

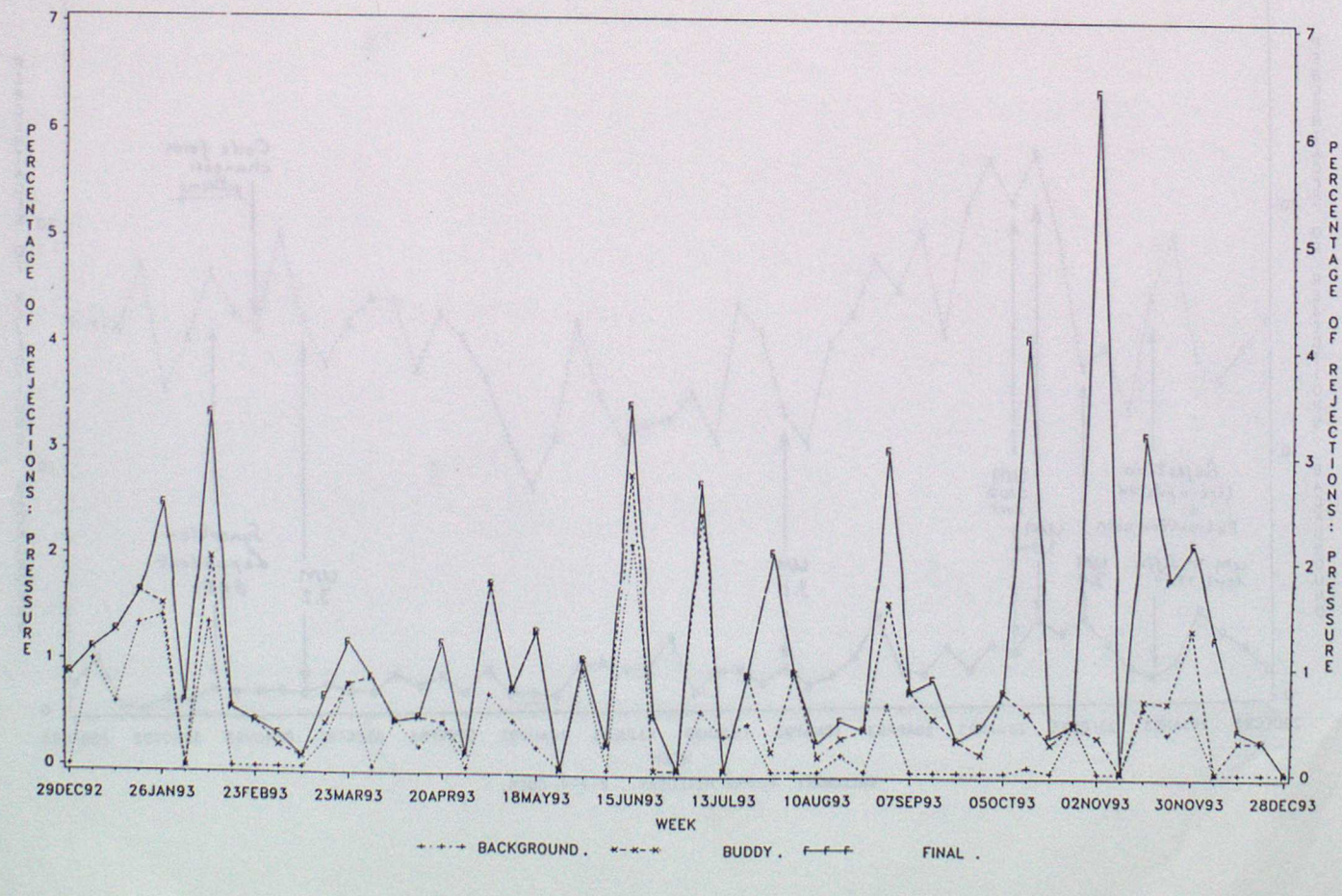


Figure 5 (b)

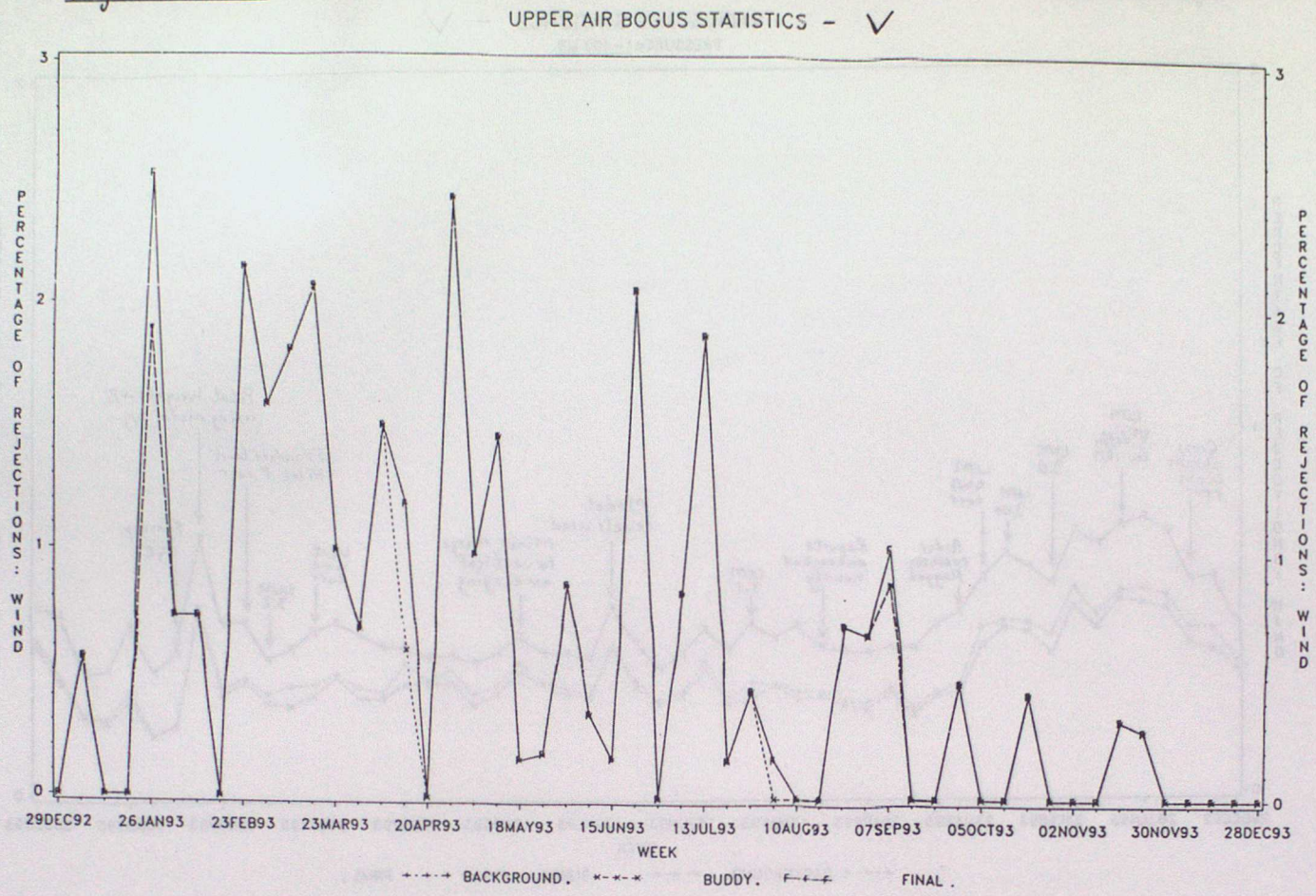


Figure 6

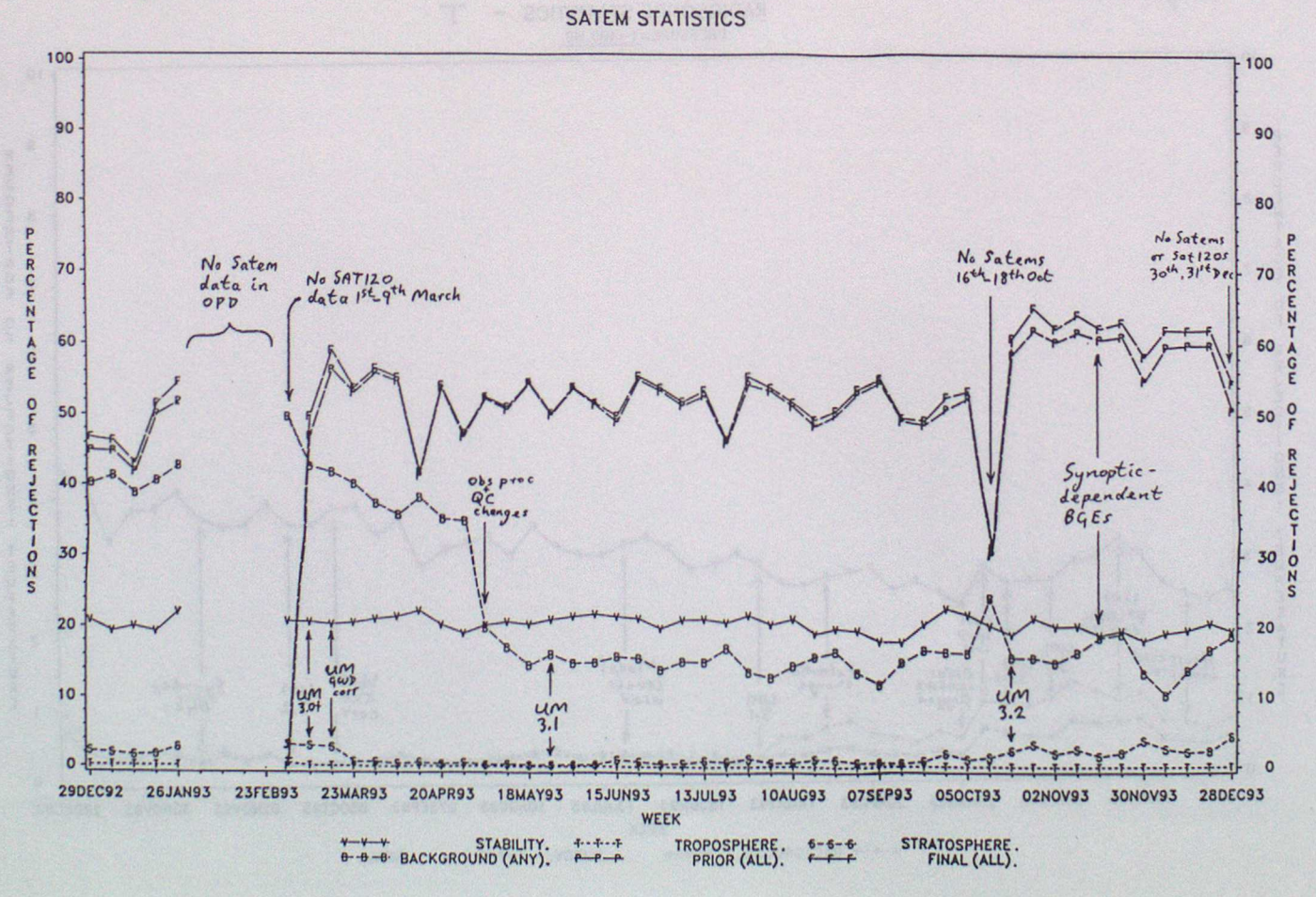


Figure 7(a)

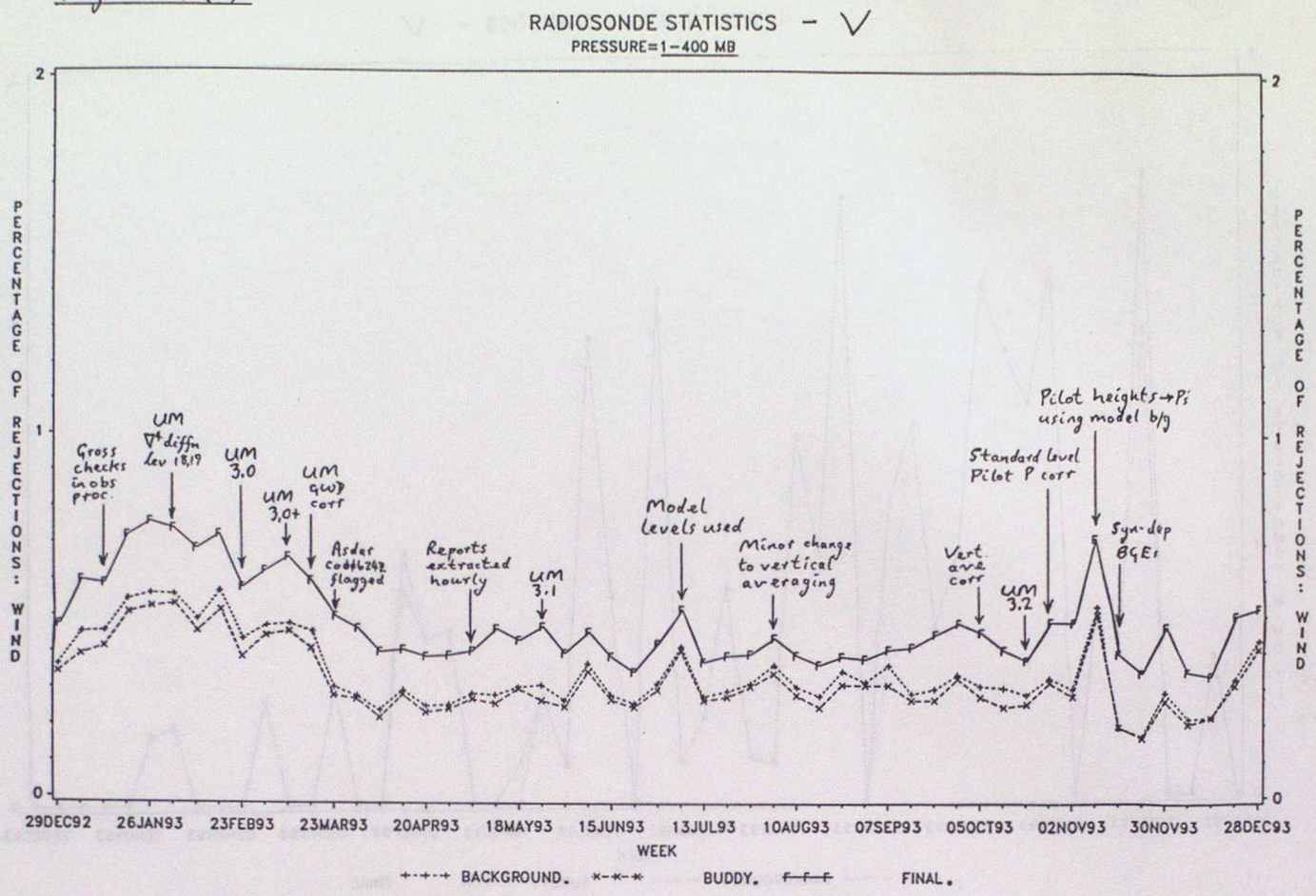


Figure 7(b)

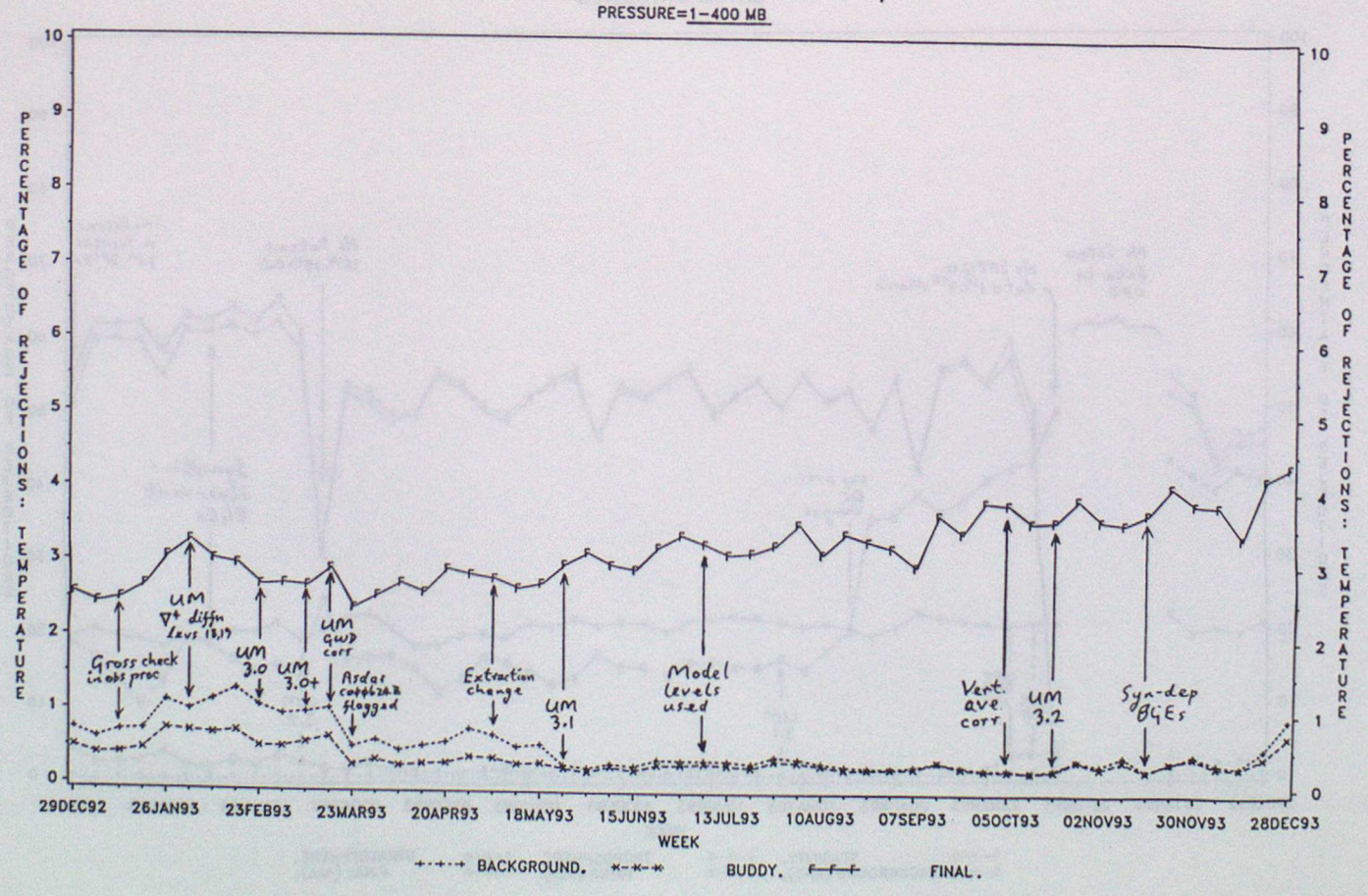


Figure 7(c)

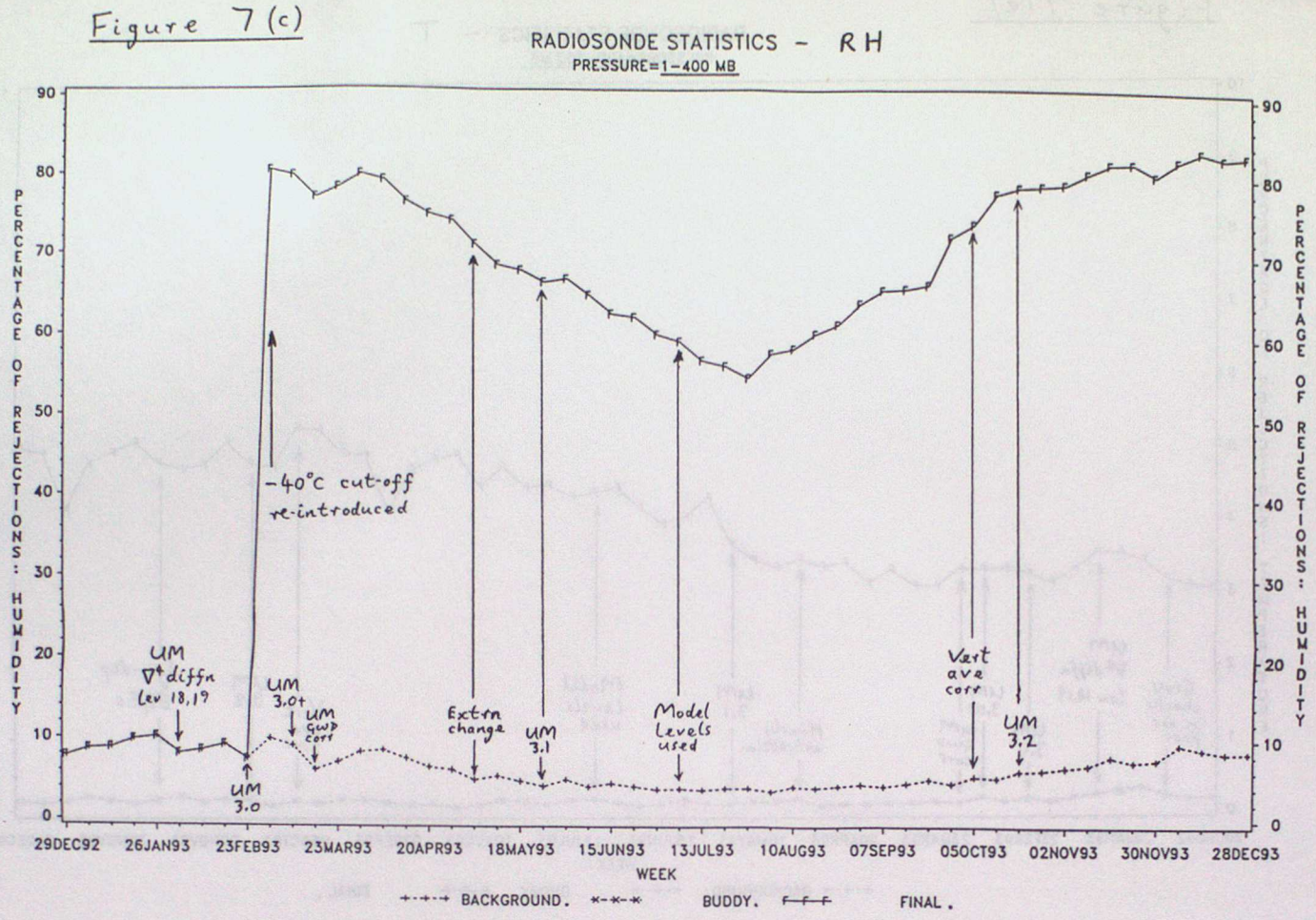


Figure 7(d)

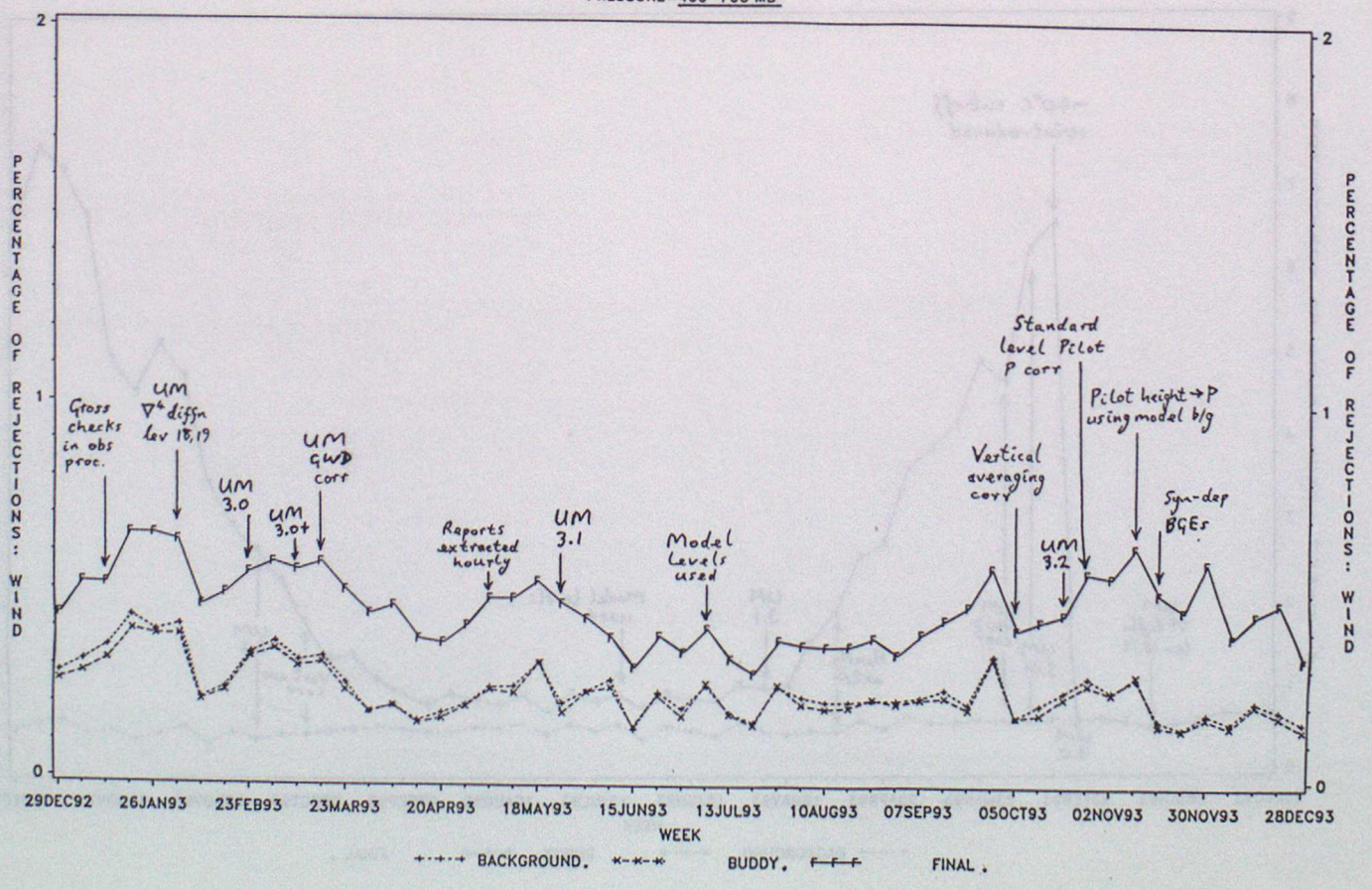
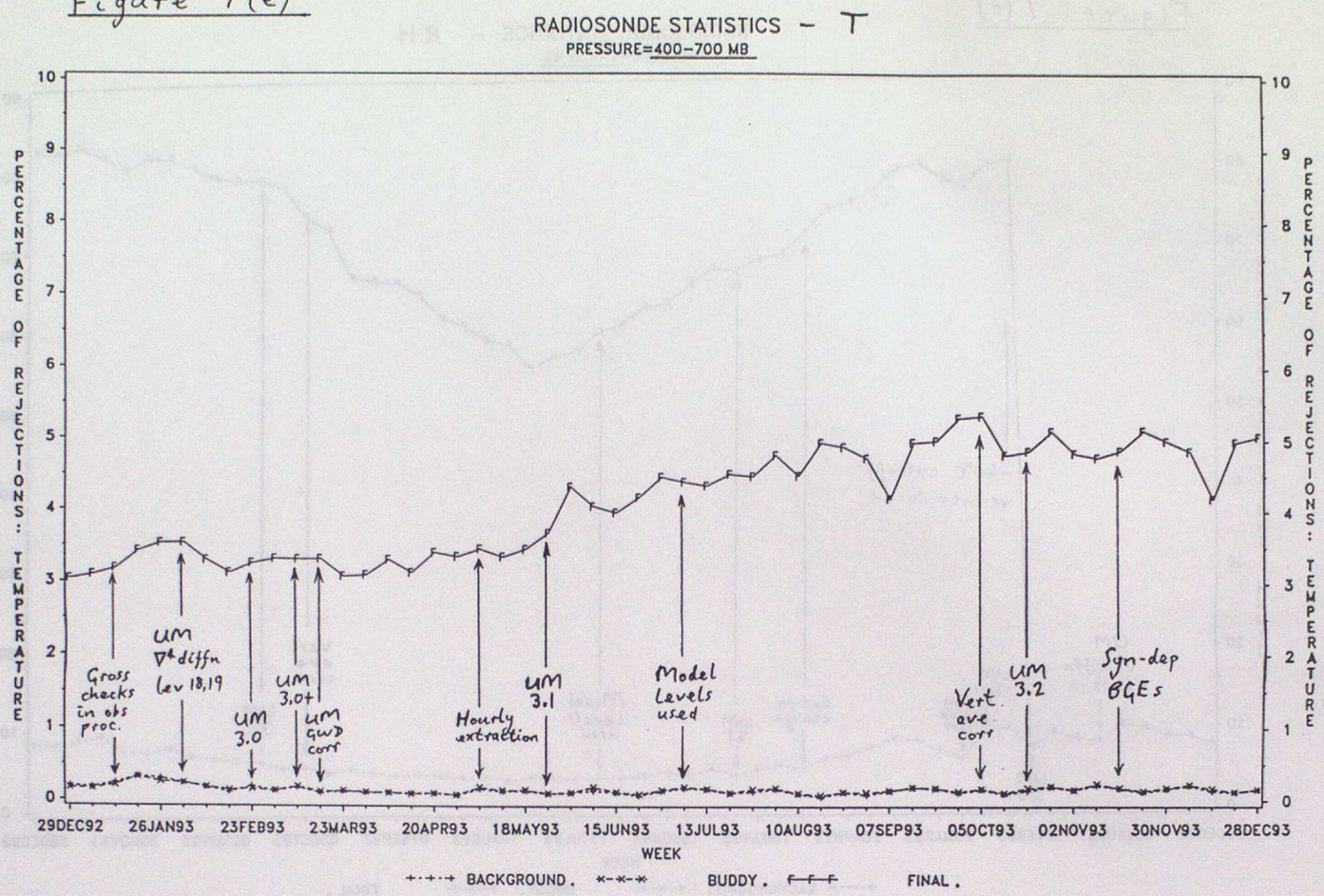


Figure 7(e)



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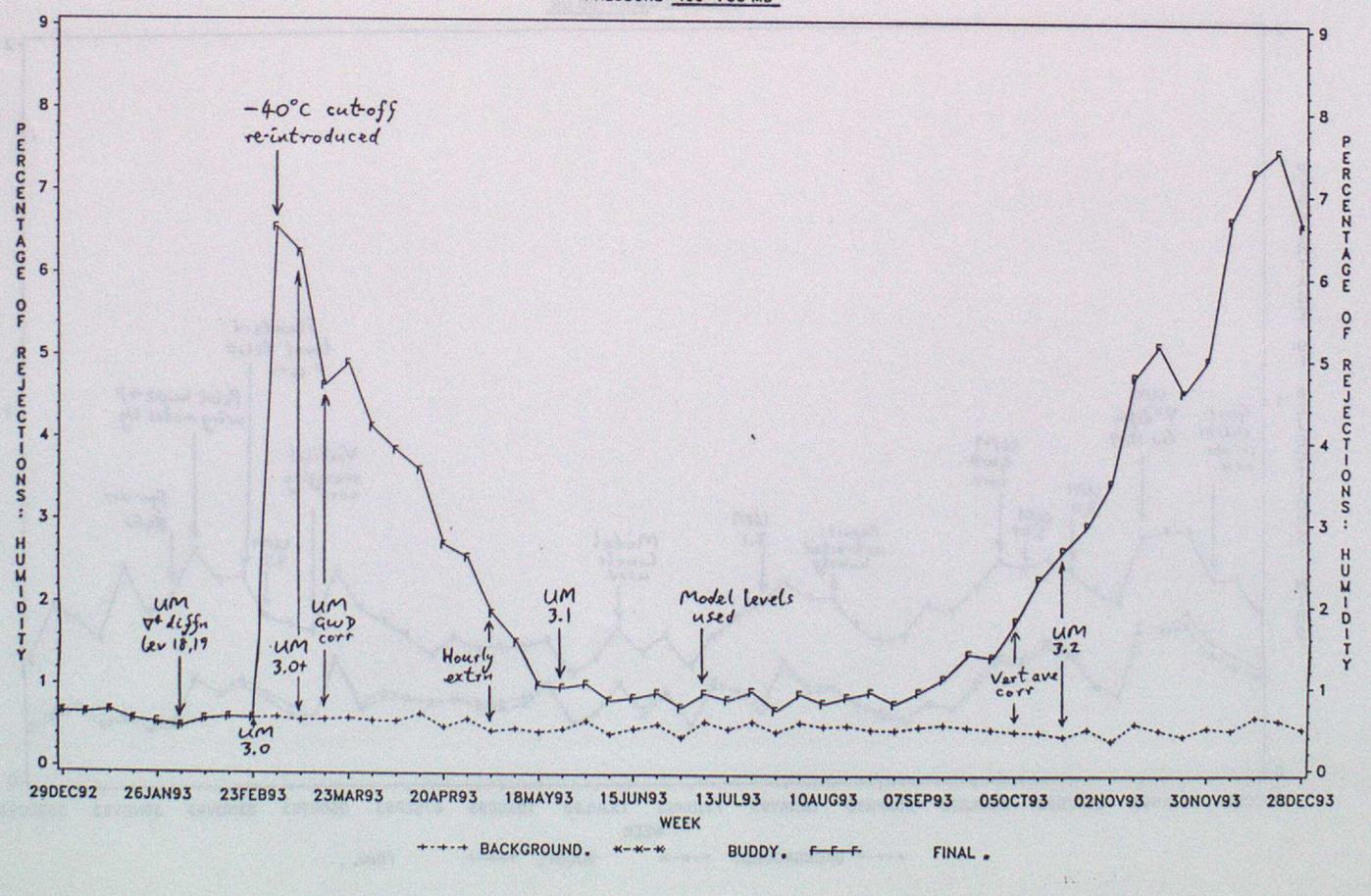

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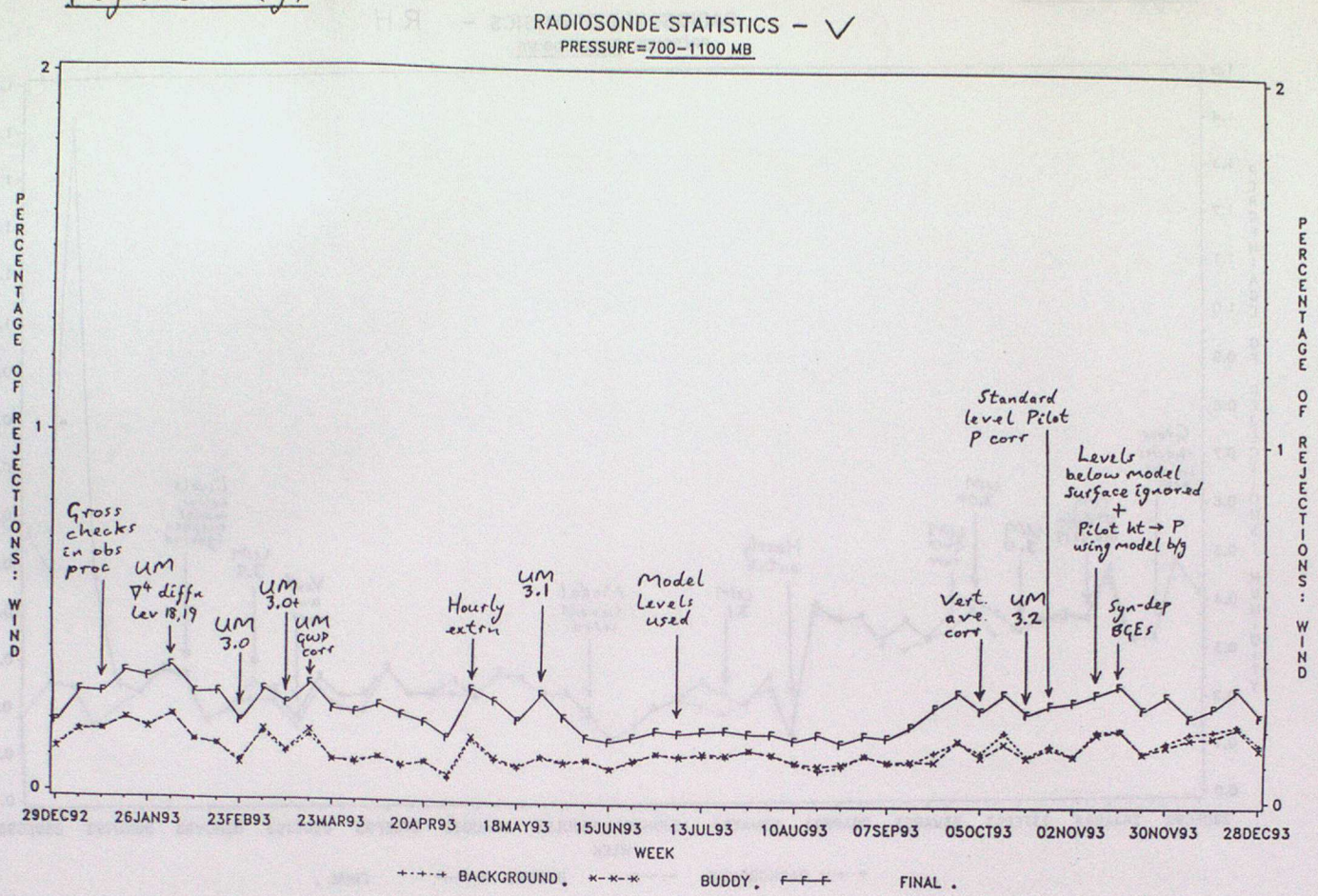


Figure 7(h)

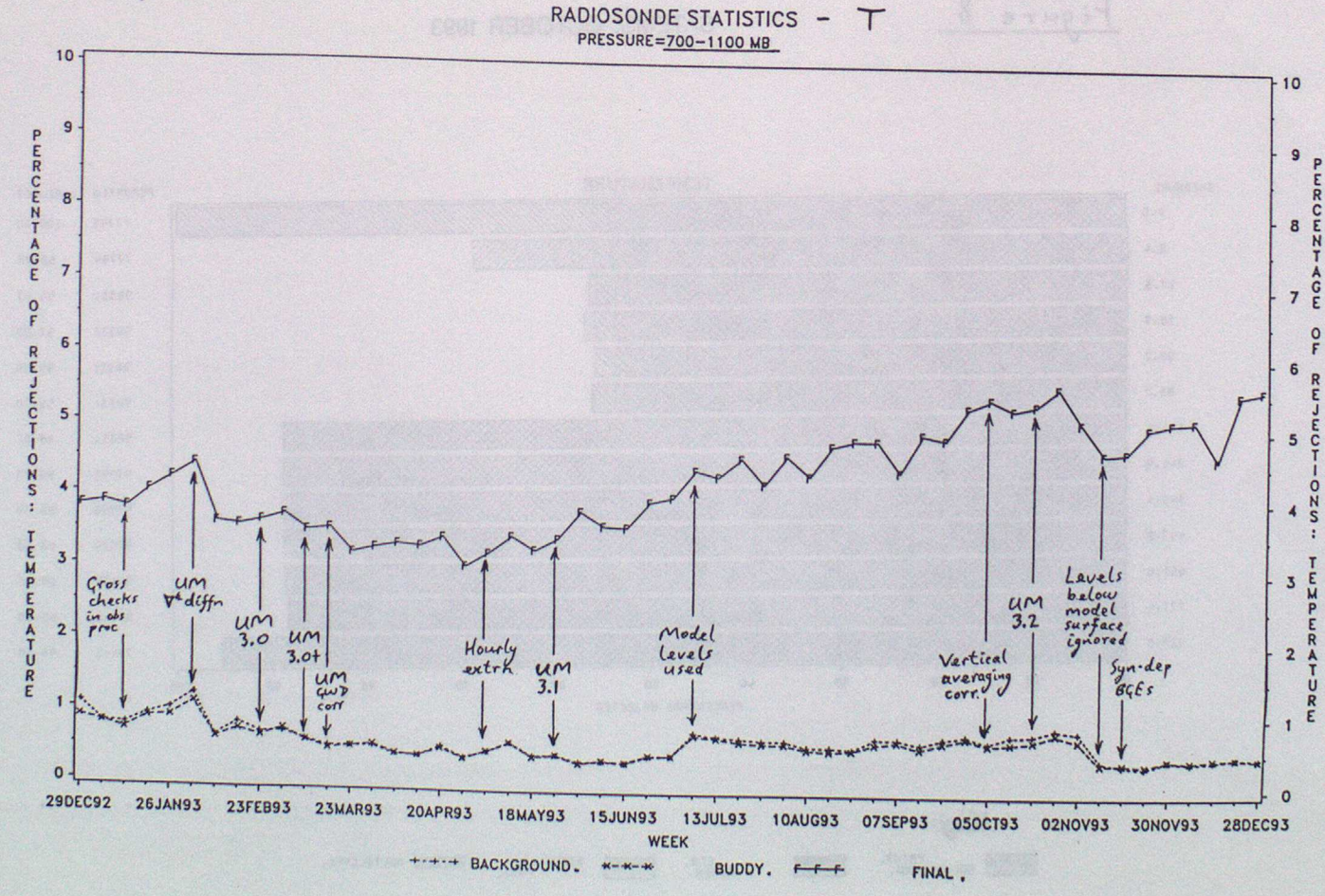


Figure 7(i)

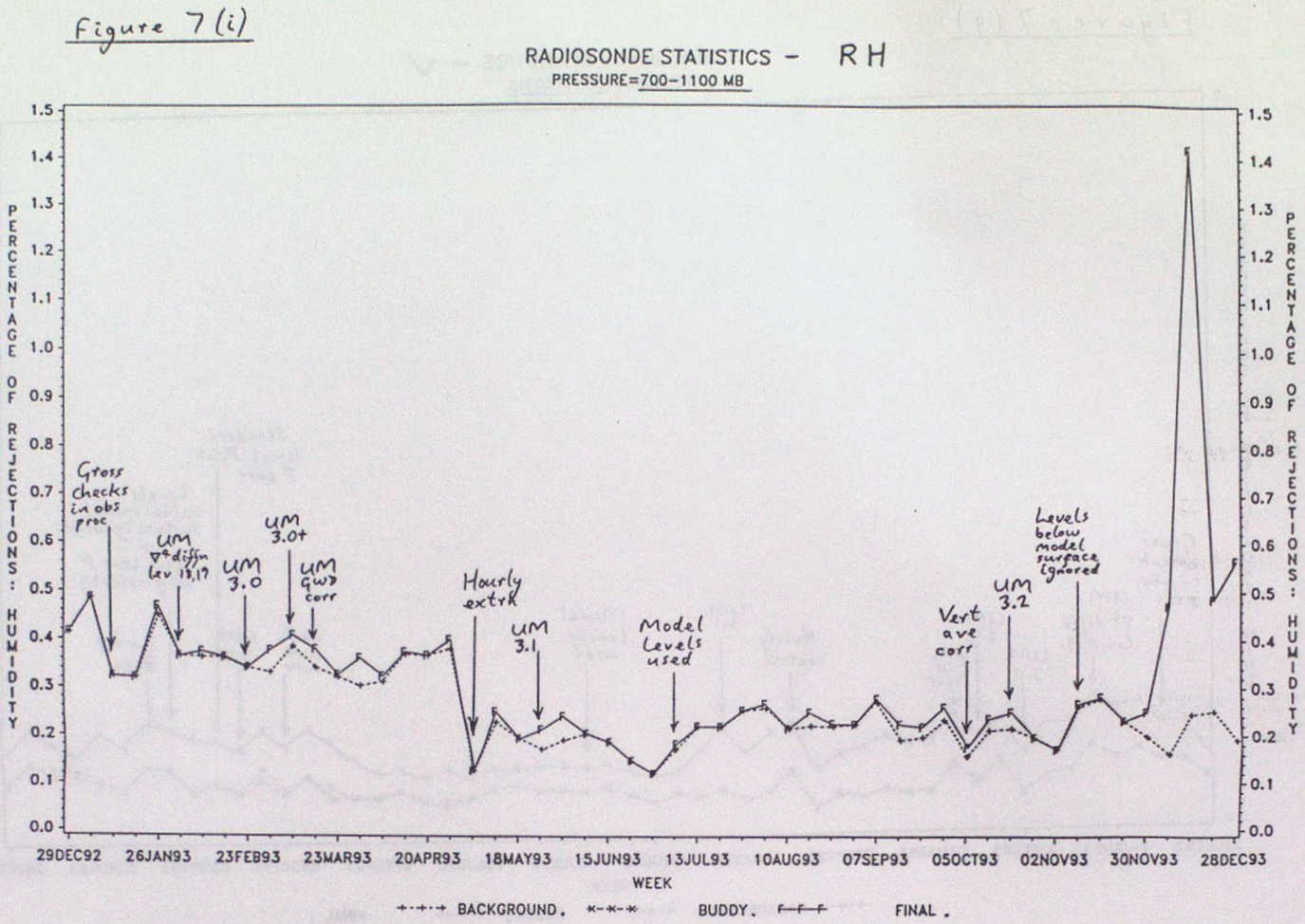
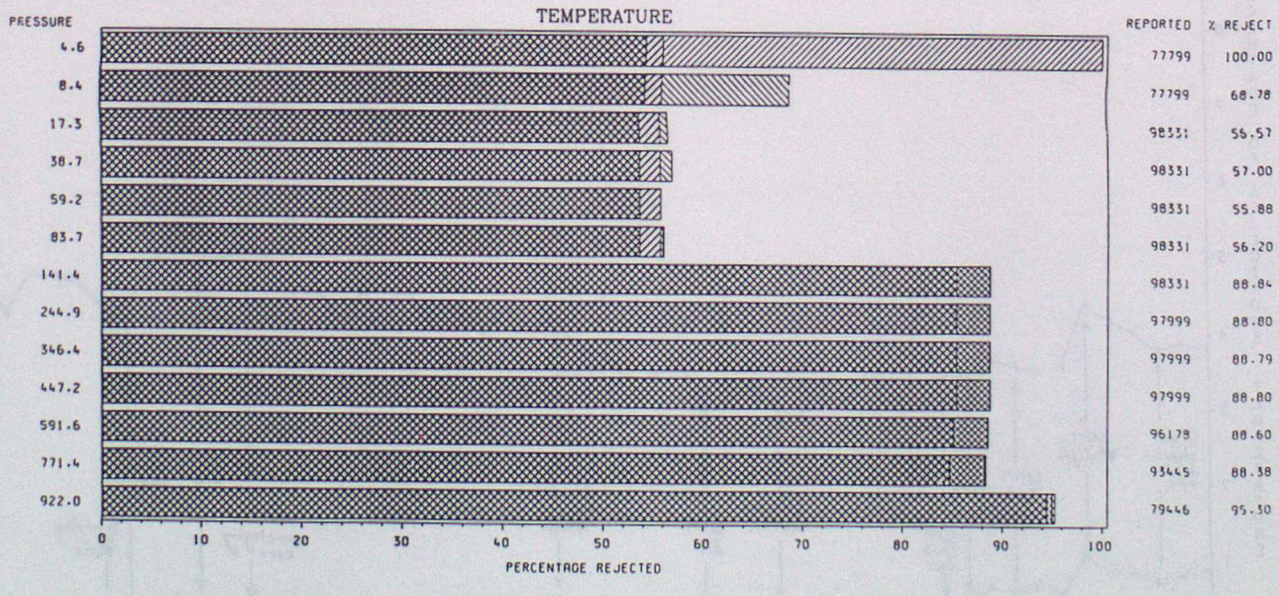


Figure 8.

SATEMS: OCTOBER 1993



Key:

PRIOR. BACKGROUND. CFO. OTHER. STABILITY. PASS. MULTILEVEL.

Figure 9(a)

RADIOSONDES: OCTOBER 1993 – WINDS

THE NOMINAL LAYER PRESSURES CORRESPOND TO P* = 1000 MB

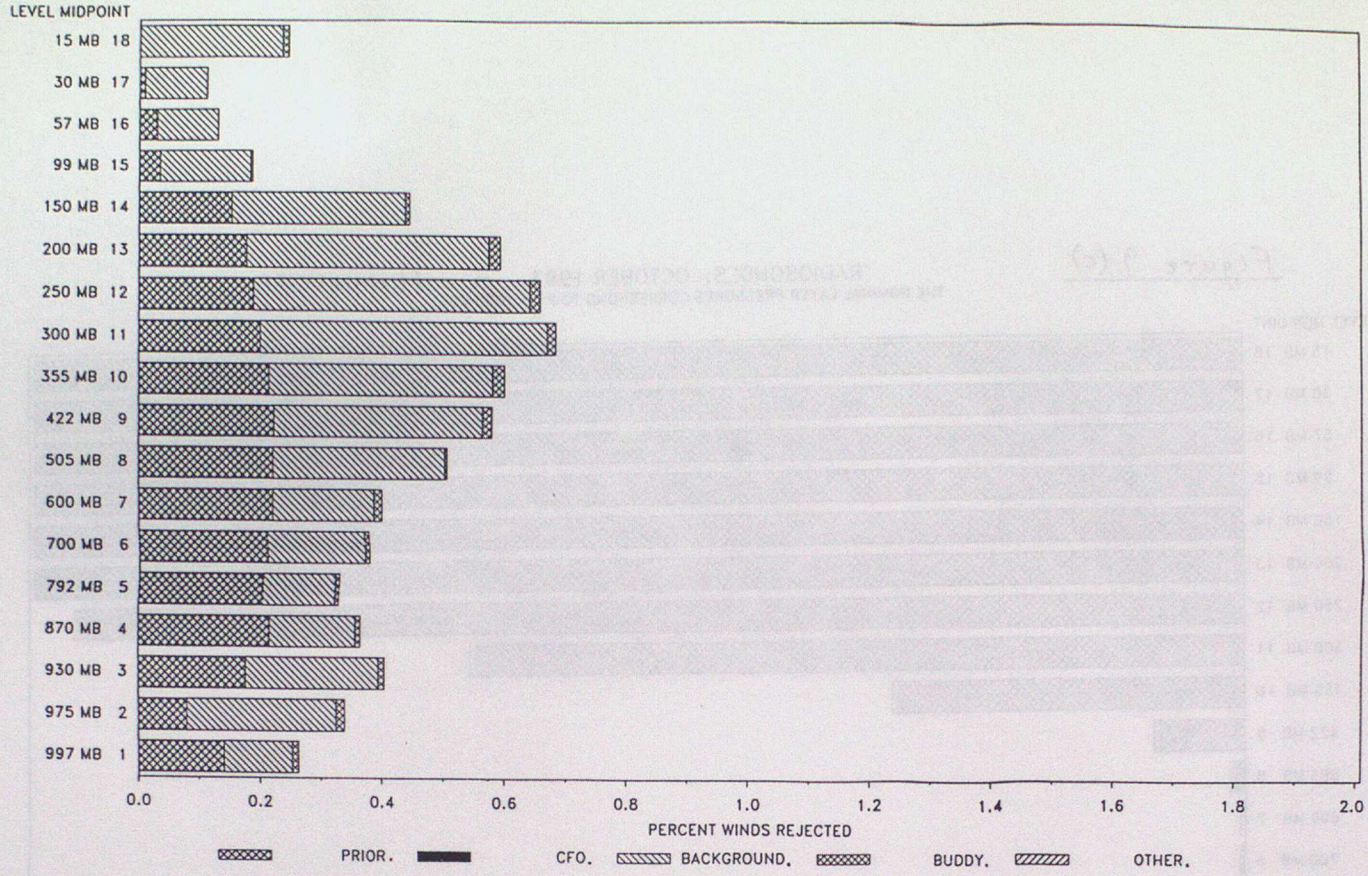


Figure 9(b)

RADIOSONDES: OCTOBER 1993 – TEMPERATURES

THE NOMINAL LAYER PRESSURES CORRESPOND TO P* = 1000 MB

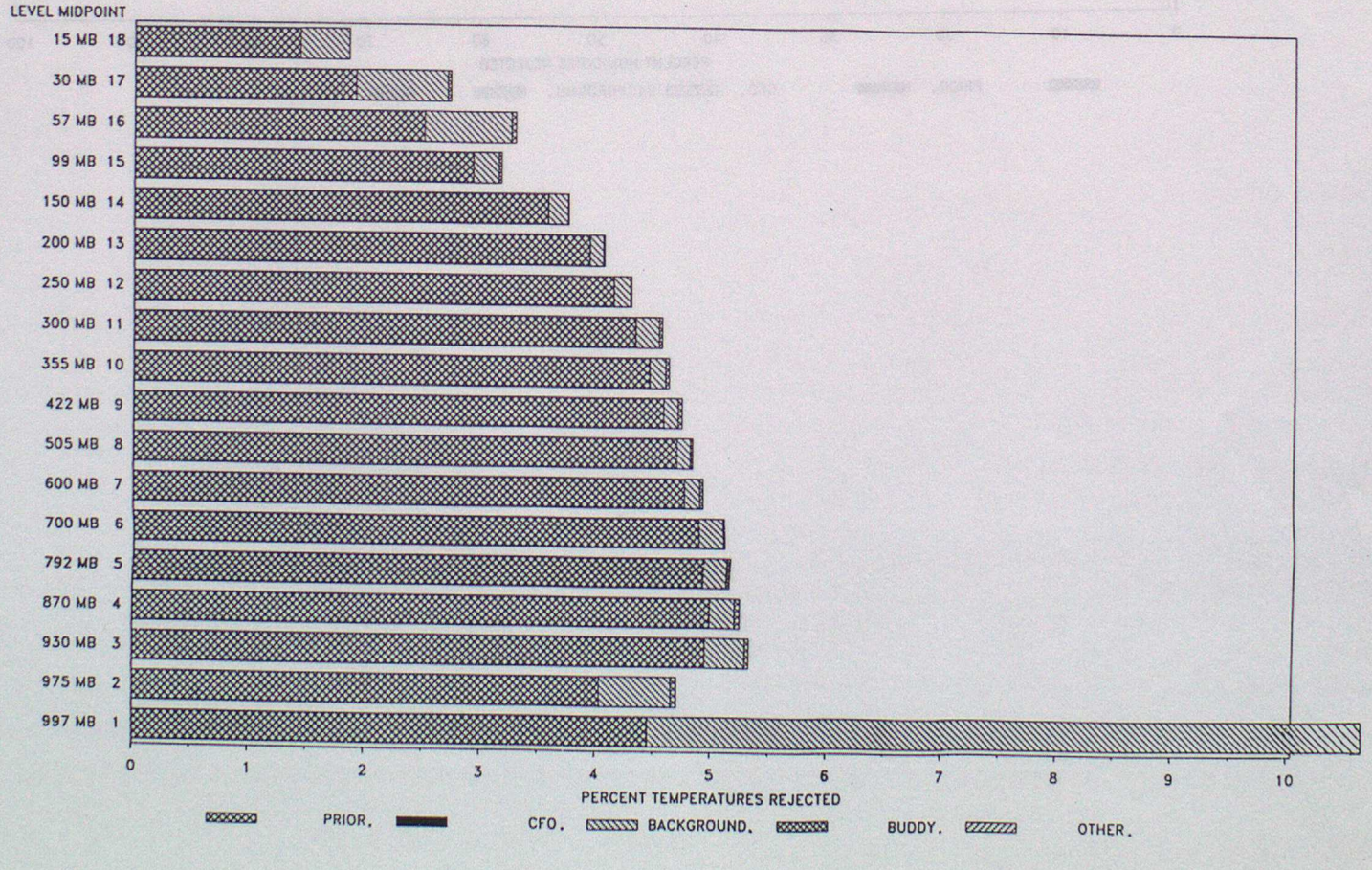


Figure 9 (c)

RADIOSONDES: OCTOBER 1993 – HUMIDITIES

THE NOMINAL LAYER PRESSURES CORRESPOND TO P* = 1000 MB